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Water Quality Goals, Objectives, and Alternatives in the Boston Metropolitan Area - A Case Study

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ABOUT THIS REPORT

The attached is one of a group of four contractor-prepared reports which collectively comprise Phase II of a government-sponsored study, "Scientific and Technical Evaluation of the Environmental Protection Agency's Wastewater Treatment Facilities Grants Planning Process - Boston Case Study." The study examines current administration of the municipal wastewater treatment facilities construction grants program established by the Federal Water Pollution Control Act Amendments of 1972 and modified by the Clean Water Act of 1977.

The reports were prepared for a federal interagency study team composed of representatives of the National Science Foundation, the President's Council on Environmental Quality, the Office of Management and Budget, and the Environmental Protection Agency headquarters. Draft copies of these reports were made available to the public in August 1978 and were the subject of agency and public meetings in September 1978. Written comments were solicited from governmental agencies, public interest groups, and the general public. They are noted and responded to by the contractors in the final printed reports.

The objective of the study was to examine recent operation of the Construction Grants Program, using the Boston Metropolitan Area as a case study, with a view toward developing recommendations for possible legislative or administrative actions at the national level to (1) improve the administration of the program in general; (2) upgrade the scientific and technical basis for decisionmaking; and (3) assure that federal funds are used in a cost effective way to achieve national water pollution cleanup goals.

The four reports comprising Phase II of this study are

Kennedy Engineers, Inc., Wastewater Treatment Facilities Planning in the Boston Metropolitan Area - A Case Study. Engineering Report. January 1979.

Environmental Research & Technology, Inc., Water Quality Goals, Objectives, and Alternatives in the Boston Metropolitan Area - A Case Study. February 1979.

Environmental Research & Technology, Inc., Sludge Management Planning in the Boston Metropolitan Area - A Case Study. January 1979.

Urban Systems Research & Engineering, Inc., Institutional Aspects of Wastewater Management: The Boston Case Study. January 1979.

Our signatures indicate that this study was conducted under our supervision, but they do not imply our agreement, individually or collectively, with the study findings, conclusions, or recommendations.

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Water quality goals, objectives, and alternatives in the Boston metropolitan area -- a case study

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"I'm not so sure it is a good idea to clean up the Charles. Maybe twenty years ago it would have been a good idea. But people don't want to swim in rivers anymore. Kids today have cars. They want to go out to the beach or swim in swimming pools."

An official in the Massachusetts DWPC, quoted in Boston After Dark 11, no. 44, 9 November 1971, p. 14.

PREFACE

The purpose of this case study was to analyze the results of water quality planning as critically as possible. This critical analysis addresses the key planning and decision documents and takes issue with the methods of analysis and the underlying assumptions, as well as with the results. This study has been controversial: it has found serious deficiencies in the water quality planning process in the Boston Metropolitan Area, and that the Wastewater Engineering and Management Plan for Boston (EMMA) will result in costs that are excessive compared to its limited expected water quality benefits. This study found, for example, that if the EMMA Recommended Plan is implemented, the water quality in the areas with the highest use potentials on the Charles and Neponset Rivers will be further degraded than it is at present, and that alternative control methods exist that may be more cost-effective and warrant further analysis. If these findings are given credence, their implications are far reaching. Hundreds of millions of dollars in various stages of funding will have to be redirected. Some of the money will have been already spent on construction of facilities and sewers that will be abandoned. The efforts of several years of planning by local and federal agency personnel will have been to little useful purpose except as experience.

The author has been sensitive to the fact that, if the findings of this study are acted on, the hundreds of millions of federal dollars slated for public works expenditure in Massachusetts will be deferred until new and better plans can be developed. This deferment will hinder the state's construction industry in the short term and will have an impact on current projections of cash inflow and employment in the state. Moreover, there will be a national impact, as federal policy makers may anticipate similar situations in metropolitan regions that have not yet been subjected to a critical case study. With this responsibility in mind, a serious attempt has been made to present as well documented and objective an evaluation as possible. This report is not intended to be a "counter plan" or an adversary document. Rather it is an examination of results, how they were arrived at and how alternative analyses could have provided different and more productive results.

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This study has in turn been evaluated and criticized. The author does not claim that this report is unassailable or even without error in all of its details. He does assert that the water quality planning process has produced far less in the way of water quality results than the public has been led to expect and that the study presents adequate evidence for this assertion. Comments and critiques have been welcomed. The objective is to contribute to better water quality management in the nation in as constructive a manner as possible. If the doubts raised in this study are given public standing, this will lead to improved water quality planning. The recognition that better planning is needed and the future possibility of clean water in Metropolitan Boston have been considered sufficient justifications for the work vested in this study.

J. Douglas Smith
January 1979

ACKNOWLEDGMENTS

This study was not conducted by the author alone. Much of the analysis of water quality standards and criteria was performed by Thomas P. Flaherty. The tedious extraction and assembly of data for the population, land-use and pollution-loading distributions calculations and for the water-use potential computations were done by Alan Gradet and Phoebe Asketh Call. The models used in the examination of urban street-cleaning dynamics and urban hydrology were developed by William W. Walker, Jr. Many insights and helpful suggestions for this study were provided by the technical reviews of Tom Flaherty, Samuel Fogel, Frederic March, and Joseph J. Harrington. To the degree that any clarity at all has emerged from the author's usually obscure and sometimes delphic ramblings it is due to the editorial capabilities and perseverance of Barbara T. Kelly. The assistance of these colleagues and friends is warmly and gratefully acknowledged.

EXECUTIVE SUMMARY

1. OVERVIEW AND SUMMARY

The Boston Case Study was conducted by a federal interagency team comprising the National Science Foundation (NSF), the Council on Environmental Quality (CEQ), the Office of Management and Budget (OMB), and the Environmental Protection Agency (EPA). The purpose of the Boston Case Study was to examine the administration and results of the U.S. Clean Water Grants Program in the Boston metropolitan area. A part of this case study was an analysis of water quality goals, objectives, and alternatives. Of particular concern was the adequacy of the Boston area water quality planning process for achieving the swimming/fishing quality waters mandated as a national goal by the 1972 Federal Water Pollution Control Act (PL 92-500).

Concern in the Boston area about water quality, particularly its sanitary significance and close relationship to public sewer systems, is documented at least as far back as 1850 with Lemuel Shattuck's historic _Report of the Sanitary Commission of Massachusetts_. By 1884, the Boston Main Drainage System (combined sewers) was completed. Construction of this system was in response to the local water quality conditions of the time, whereby "large (surrounding) territories were at once, and frequently, enveloped in an atmosphere of stench so strong as to arouse the sleeping, terrify the weak, and nauseate and exasperate everybody." By 1905, construction of much of the plumbing for the present Metropolitan Sewerage District (MSD) had been completed. In 1910 construction of the Charles River Dam at Leverett Street in Boston was completed. This dam was designed to prevent tidal flooding of low-lying sewers along the Charles River estuary, to create a constant level recreational basin, and to cover the unsightly and foul-smelling mud flats that received the overflows from the combined sewer systems of Boston and Cambridge. In 1919 the Metropolitan District Commission (MDC) was created to assume the functions of the Metropolitan Parks Commission, as well as to administer the MSD. In 1936, a _Report of the Special Commission on the Investigation of the Discharge of Sewerage into Boston Harbor_

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and Its Tributaries (Massachusetts House Document 1600) documented objectionable water quality conditions in the vicinities of the main sewer system outlets in Boston Harbor and at combined sewer overflow outlets. The report recommended a series of corrective measures such as treatment of sewage before its discharge to Boston Harbor, separation of combined sewer systems to prevent overflows, elimination of surface and stormwater from the MSD system, measurement of sewage entering the MSD system and charging tributary communities according to their sewage flows, and closure of bathing beaches on the Boston Harbor waterfront and its tributaries. Since 1936 scores of studies and reports have described similar water quality conditions and recommended plans and programs for their alleviation. The most recent water pollution control program proposed for Boston Harbor and its tributaries was the Wastewater Engineering and Management Plan for Boston Harbor - Eastern Massachusetts Metropolitan Area (EMMA) developed by the MDC and its principal engineering consultant, Metcalf & Eddy, Inc. Other agencies participating with the MDC as members of the EMMA Technical Subcommittee were:

U.S. Army Corps of Engineers (COE), New England Division

Massachusetts Department of Environmental Quality Engineering (DEQE)

U.S. Environmental Protection Agency (EPA), Region I

Metropolitan Area Planning Council (MAPC)

EMMA Citizens Advisory Committee (CAC)

The final report for the EMMA study was completed in March 1976 and was released in June, after the public hearing and comment period for the MDC's NPDES permit for Boston Harbor and tributaries, which was based directly on the EMMA recommended construction program. Although the EMMA Recommended Plan was originally intended to determine present and future wastewater management needs of the MDC, it was subsequently approved by EPA Region I as the Sec. 303(e) Water Quality Management Plan for Boston Harbor and its major tributaries. As such, it became the focal point of this analysis of water quality goals, objectives, and alternatives in the Boston metropolitan area.

The EMMA Recommended Plan included expansion and upgrading to secondary treatment of the existing Boston Harbor primary treatment plants at Deer and Nut Islands, new satellite advanced waste treatment (AWT) plants discharging to the Charles and Neponset Rivers, several detention/chlorination facilities for combined sewer overflows to the Harbor and tributaries, and various relief sewers, interceptor extensions, pumping station replacements, and miscellaneous system repairs. The EMMA plan recommended expansion, by the year 2000, of the present MSD from 43 communities to 51, and assumed increased per capita water use as well as continued infiltration/inflow into existing MSD sewers. These assumptions resulted in wastewater flow projections of 274 gallons per capita per day, for example, from the Deer Island service area by the year 2000.

Today, water quality in the Boston metropolitan area has been seriously degraded at virtually every location. Only in Quincy Bay and at some locations in the Dorchester Bay section of Boston Harbor is there swimming/fishing quality water, and even these locations are restricted or closed for shellfish harvesting. Water quality is generally poorest at those locations most accessible to potential beneficiary populations. The primary pollution problems in Boston Harbor and tributary estuaries are the result of combined sewer overflows and urban stormwater runoff. Upstream in tributary rivers, the primary pollution problems result from discharges of inadequately treated sewage effluents, urban stormwater runoff, and nonpoint sources. The EMMA Recommended Plan does not include any facilities for control of pollution from urban stormwater runoff or from nonpoint sources. It does not address the quantitative water quality needs in the Boston metropolitan area, nor does it establish the total maximum daily pollutant loads allowable for those waters as required by Sec. 303 of PL 92-500. A principal finding of the Boston Case Study is that the $855 million EMMA Recommended Plan, if implemented, would not produce significant water quality improvements. At the most publicly accessible locations, already poor water quality would become worse.

2. METHOD OF STUDY

This case study attempted to follow the water quality management planning steps detailed in Sec. 303 of PL 92-500. The study began with an examination of existing and historical water quality goals in the Boston metropolitan area, as exhibited in the Massachusetts Water Quality Standards, water quality criteria, water use classifications, and the conflicting priorities for meeting those uses. A modified system of use classifications and water quality criteria was then developed to reduce the many ambiguities present in the Massachusetts System (1974 standards). This alternative system was then used in subsequent analytical steps as the description of water quality objectives for the area. Available data from water quality surveys, basin plans, and other information sources were analyzed to develop descriptions of existing water quality and specific pollution problems in Boston Harbor and its three major tributary rivers.

Boston Harbor and the Charles, Mystic, and Neponset River Basins were divided into 19 water quality sections, according to locations of tributaries, diversions and pollutant inflows, and drainage area characteristics. Critical, or controlling, water quality parameters for each section were identified. Average daily existing (year 1970) and projected (year 2000) pollutant loadings were estimated for each section. Simplified empirical models were developed to relate estimated pollutant loadings to available receiving water quality data. These models were then used to estimate the maximum daily loads of critical pollutants that would permit achievement of the swimming/fishing quality criteria for each of the 19 water quality sections.

Pollutant reduction capabilities and cost information were assembled for a number of representative structural and nonstructural control technologies. Technologies considered were those for control of point sources, combined sewer overflows, and urban stormwater discharges. Not explicitly considered were specific control technologies for rural and suburban nonpoint sources. These technologies were assembled into a number of alternative management strategies that were developed by the Boston Case Study team and then analyzed for their respective impacts on receiving water quality.

A method was developed in this study to estimate the relative benefits of swimming/fishing quality waters at alternative locations in the Boston metropolitan area. The method was based on observations of local willingness-to-pay and recreational benefit surveys that public water quality priorities correlate most strongly with public proximities to alternative water locations. The ratios of relative clean water benefits to pollution control costs were then used as the cost-effectiveness comparisons among alternative water quality management strategies. This method of comparison thus explicitly included measures of pollution severity (control costs) as well as water uses (benefits) according to the priority ranking system requirements of Sec. 303(d).

3. WATER QUALITY STANDARDS

The water quality management planning process for each state, detailed in Sec. 303(c), begins with a requirement for water quality standards, which shall consist of the designated uses of the navigable waters involved and the water quality criteria for such waters based on such uses.

This analysis found the Boston area water quality planning process to contain many flaws from its start, with water quality standards that were vague, that confused water quality criteria with effluent limitations and placed undue confidence in an ability to distinguish between conditions resulting from "natural" compared to "artificial" circumstances.

Sec. 303(d) requires that each state identify those waters where the effluent limitations imposed by Sec. 301 (secondary treatment for municipal discharges) are not stringent enough to implement applicable water quality standards. For such waters, each state shall establish maximum daily pollutant loads at levels necessary to implement applicable water quality standards, these levels to consider seasonal variations and include a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

This study found that the Massachusetts Division of Water Pollution Control (DWPC) 303(d) segmentation and classification process did not correctly identify the Charles River Basin, Boston Inner Harbor, and Dorchester Bay according to either the requirements of Sec. 303(d) or its own clean criteria for "water quality limited" segments. Maximum daily loads for critical pollutants were not established for Boston area waters. The DWPC was also reluctant to classify for swimming/fishing uses those waters nearest the greatest potential user populations irrespective of public testimony and documentation to the contrary.

For this study, all major Boston metropolitan area waters were considered as classified for swimming/fishing uses (Class B or SB), except for those already classified for higher uses (e.g., public drinking water supplies). Alternative water quality criteria, intended to clarify existing standards, were developed and used as subsequent water quality objectives in this analysis. For Boston area waters, the critical water quality parameters were considered to be coliform bacteria, color and turbidity, nutrients, and - secondarily - dissolved oxygen. The swimming/fishing criteria for these parameters in inland fresh waters (Class B) and marine and coastal waters (Class SB) that: (1) existed in the 1974 Massachusetts Standards, (2) were developed and recommended in this analysis, and (3) were subsequently adopted in the 1978 Massachusetts Standards are compared in Table 1.

The precise language of the coliform criteria recommended in this report was intended to clarify the statistical ambiguity of the 1974 Massachusetts Standards and to take into account the temporal fluctuations characteristic of waters influenced by runoff and sewer overflows. The 1978 Massachusetts coliform Class B criterion does not seem to allow the log mean of any sample set to exceed 200 fecal coliforms per 100 ml. [A log mean cannot include either zero or too many to count (TMC) values.] The Class SB criterion, on the other hand, seems to require only that the median of all samples during any monthly sampling period not exceed a total coliform MPN of 700 per 100 ml. The 1978 criteria for color and turbidity and for nutrients remain as tautological as the 1974 criteria. The dissolved oxygen criteria has been improved in the 1978 standards although the 6.0 mg/l numerical value for Class SB waters is quite likely higher than necessary for this water use.

TABLE 1

COMPARISONS OF WATER QUALITY CRITERIA

1974 Massachusetts Criteria	Recommended Criteria	1978 Massachusetts Criteria
	COLIFORM BACTERIA	
	Class B Waters	
(Total Coliforms) Not to exceed an average value of 1,000 nor more than 1,000 in 20% of the samples.	(Fecal) Based on a minimum of not less than five sample sets taken over a 30-day period, the arithmetic mean of the medians of the sample sets shall not exceed 200 per 100 ml nor shall more than 10% of the samples exceed 400 per 100 ml.	(Fecal) Shall not exceed a log mean for a set of samples of 200 per 100 ml, nor shall more than 10% of the total samples exceed 400 per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.*
	Class SB Waters	
(Total Coliforms) Not to exceed an average value of 700 and not more than 1,000 in more than 20% of the samples.	(Fecal) Based on a minimum of not less than five sample sets taken over a 30-day period, the arithmetic mean of the medians of the sample sets shall not exceed 200 MPN per 100 ml nor shall more than 10% of the samples exceed 400 MPN per 100 ml.	(Total Coliforms) Shall not exceed a median value of 700 MPN per 100 ml and not more than 20% of the samples shall exceed 1,000 MPN per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.*
	COLOR AND TURBIDITY	
	Class B and SB Waters	
None in such concentrations that would impair any uses specifically assigned to this class.	A Secchi disc shall be visible at a minimum depth of 4.0 feet or on the bottom if the water is less than 4.0 feet deep.	Shall not be in concentrations or combinations that would exceed the recommended limits on the most sensitive receiving water use.
	NUTRIENTS	
	Class B and SB Waters	
Any existing discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be treated to remove such nutrients to the maximum extent technically feasible.	Shall not be present in concentrations greater than that which would result in an algal biomass greater than that corresponding to a chlorphyll-a concentration of 25 µg/l.	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
	DISSOLVED OXYGEN	
	Class B Waters	
Not less than 75% of saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l at any time. For cold water streams, the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams, the dissolved oxygen concentration shall not be less than 6 mg/l during the season.	Minimum of mg/l.	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
	Class SB Waters	
Not less than 5.0 mg/l at any time.	Minimum of 5.0 mg/l.	Shall be a minimum of 6.0 mg/l.

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*Regulation 2.1 allows seasonal (Oct. 15-Apr. 1) discontinuation of effluent disinfection at the discretion of the Division.

4. EXISTING WATER QUALITY IN METROPOLITAN BOSTON

The general Boston Harbor area and the DWPC use classifications of its waters are shown in Figure 1. (Class SA allows unrestricted shellfish harvesting, Class SB allows swimming, and Class SC allows fishing.) Also shown are the water quality sections used in this analysis (BH1-4). Coliform bacteria is the controlling water quality parameter for all of Boston Harbor. If chlorination of combined sewer overflows, however, was interpreted as not much more than a cosmetic approach to this pollution problem, as it is so argued in this study, then dissolved oxygen would also become a critical parameter in the Inner Harbor. Boston Inner Harbor is presently used only for nagivation, industrial cooling water, and waste disposal. Pollution in this area is overwhelming from combined sewer overflows and urban stormwater, both directly into the harbor and indirectly through the Charles and Mystic Rivers. Coliform bacteria in excess of 100,000 organisms per 100 ml, high turbidity, and low dissolved oxygen characterize water quality in Boston Inner Harbor. Dorchester Bay in Boston Harbor is the most intensively used water recreation area in metropolitan Boston. Water quality in Dorchester Bay is dominated by combined sewer overflows, primarily into the southern area of the bay and the mouth of the Neponset River. Coliform concentrations, particularly near the mouth of the Neponset, exceed the Massachusetts (1974) swimming quality criterion during and for some time after rainfall events although the concentrations are less than 10% of those found in the Inner Harbor. The principal source of pollution in Quincy Bay is stormwater runoff from the City of Quincy although the effluent from the Nut Island primary treatment plant is also discharged along the seaward edge of the bay. Coliform concentrations in this area routinely satisfy the Massachusetts swimming quality criterion, but do exceed the unrestricted shellfishing criterion. By other measures, water quality is presently acceptable in Quincy Bay. The Deer Island treatment plant outfall, the largest single point source in the Boston metropolitan area, is located at the seaward edge of Boston Outer Harbor. Sludge from both Deer and Nut Islands is also discharged at this location on outgoing tides. Coliform concentrations are consistently in violation of the Class SB criterion throughout most

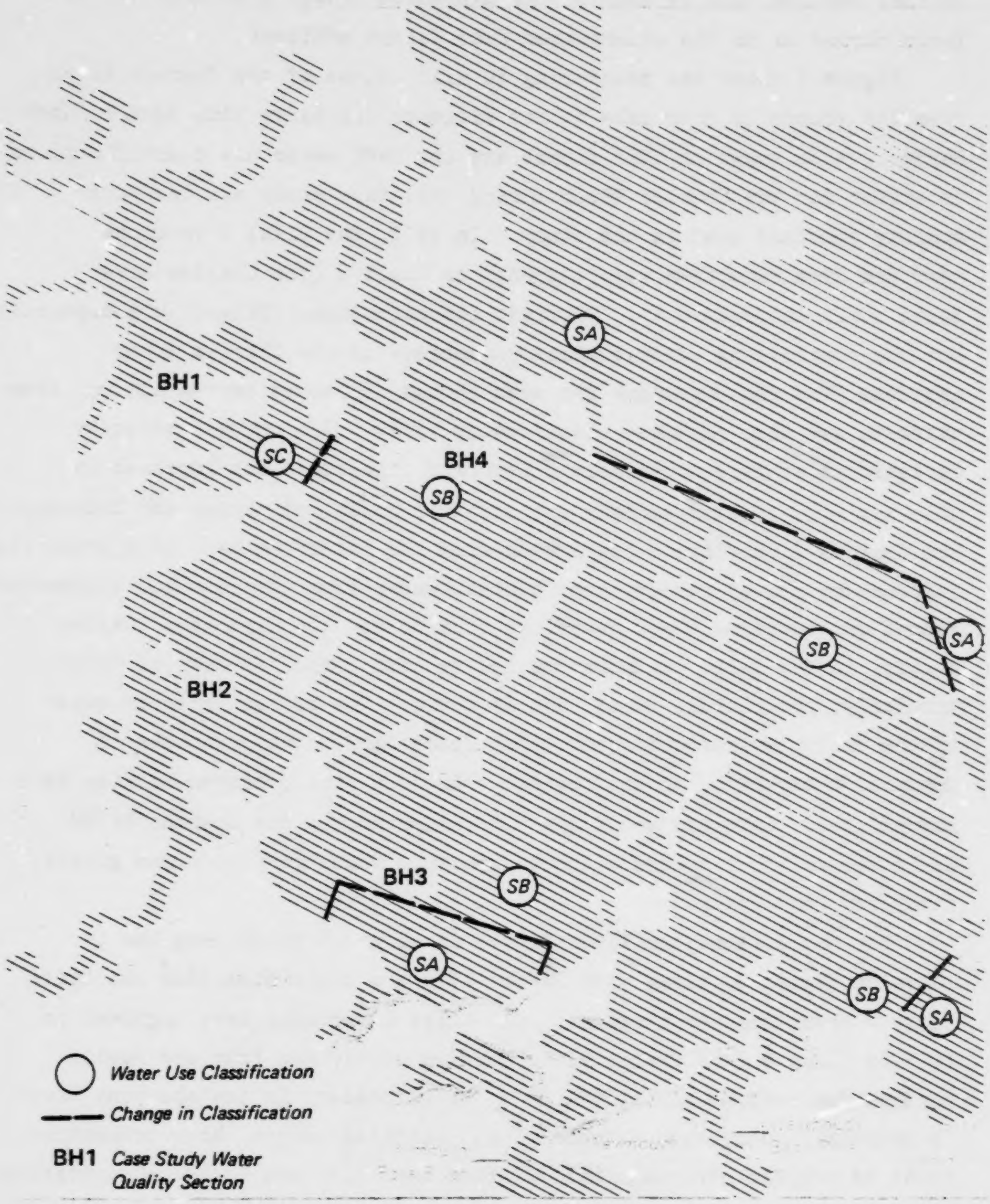
SA
BH1
SC
BH4
SB
SB
SA
BH2
BH3
SB
SA
SB
SA
Water Use Classification
Change in Classification
BH1 Case Study Water Quality Section

Figure 1 Boston Harbor

of this section, due as much to the untreated sewage overflows to the Inner Harbor as to the chlorinated Deer Island effluent.

Figure 2 shows the meandering 80-mile course of the Charles River from its source in Echo Lake to its ultimate discharge into Boston Inner Harbor. Also shown on this figure are the DWPC water use classifications in effect for the Charles River during this case study and the water quality sections used in the study. In 1978, the Class C sections upstream from Watertown were upgraded to Class B (the Charles River Basin still is classed C). Nutrient concentrations (primarily phosphorus) are the controlling water quality parameters in the Charles River upstream from the Watertown Dam even though dissolved oxygen and coliform criteria are also violated consistently today. Any control strategy designed to achieve acceptable phosphorus concentrations appeared in this analysis to also satisfy criteria for dissolved oxygen and bacteria. The Charles River Basin, downstream from the Watertown Dam, is a stratified impoundment fed by already poor quality water from upstream and stormwater runoff and combined sewer overflows from Boston and Cambridge. Water quality in the basin is characterized by high concentrations of color, turbidity, phosphorus, algae, and bacteria. The bottom layer of water in the basin is anaeorbic salt water where large concentrations of ammonia, phosphorus, exotic organic compounds, and hydrogen sulfide have accumulated. Critical water quality parameters in the Charles River Basin are coliform bacteria and phosphorus, which control algae growth, turbidity, and color.

The Mystic-Aberjona River System is about 18 miles long and is shown in Figure 3, along with DWPC's 1974 use classifications and this study's water quality sections. All Class C sections were upgraded in 1978 to Class B (the Mystic River section downstream from the Amelia Earhart Dam remains classified SC). Water quality in the Aberjona River is uniformly poor, with extremely low dissolved oxygen, high concentrations of organic materials and coliform bacteria, and toxic concentrations of nitrogen compounds. The Upper Mystic Lake contains toxic concentrations of zinc and ammonia-nitrogen and low dissolved oxygen. The Lower Mystic Lake is stratified by a large volume of anaerobic salt water trapped in the bottom of the lake. Offensive summer algal blooms in the surface waters result from excessive nutrient concentrations. The

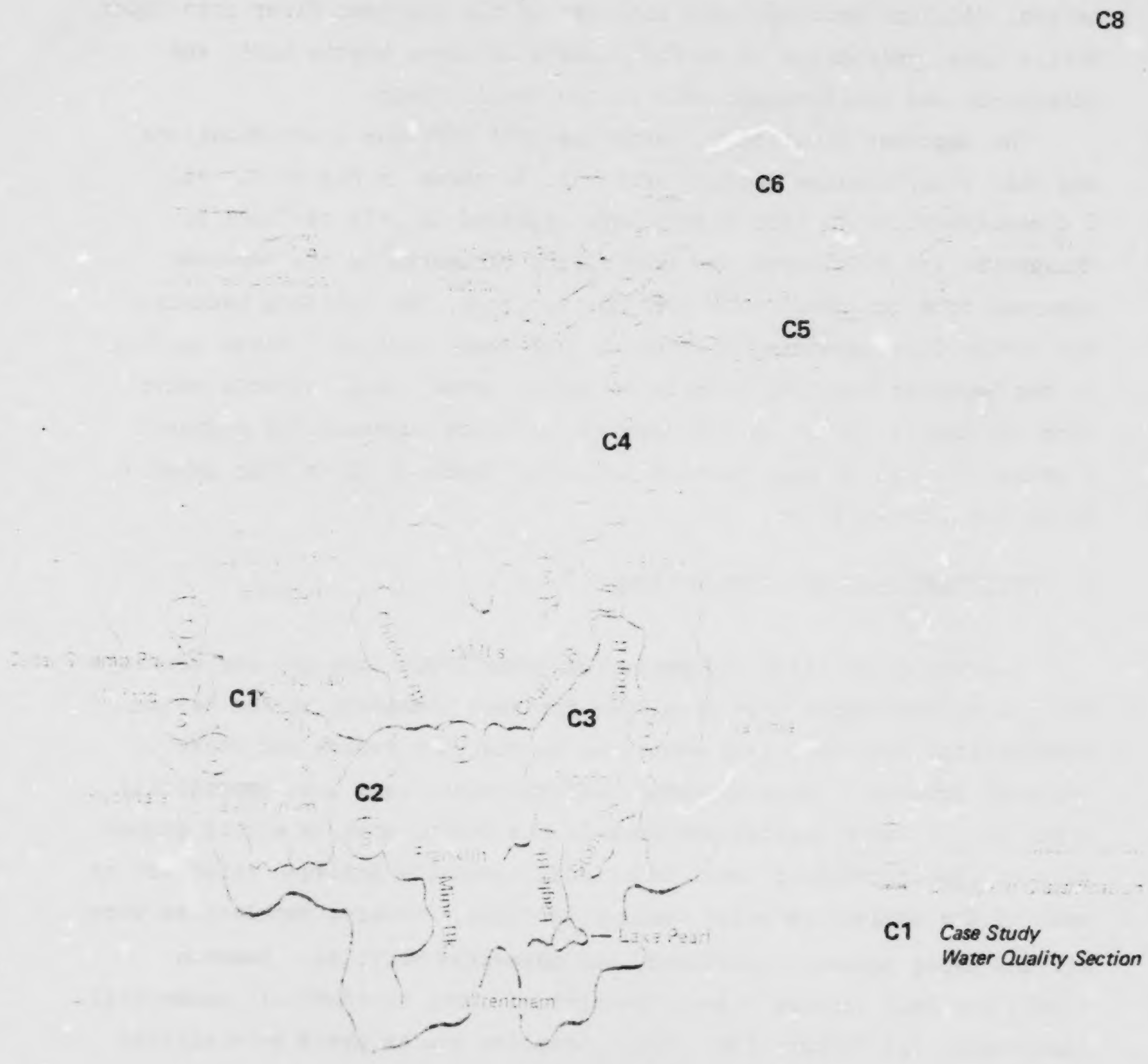
C8
C6
C5
C4
C1
C3
C2
Franklin
Mine Bk.
Lake Pearl
Wrentham
C1 Case Study
Water Quality Section

Figure 2 Charles River Basin

Mystic River from the outlet of Lower Mystic Lake to Boston Inner Harbor is polluted by combined sewer overflows and urban stormwater runoff, which result in excessive concentrations of nutrients and coliform bacteria. Controlling water quality parameters are: dissolved oxygen, coliform bacteria, and nitrogen in the Aberjona River into Upper Mystic Lake; phosphorus in surface waters of Lower Mystic Lake; and phosphorus and coliform bacteria in the Mystic River.

The Neponset River Basin, with the 1974 DWPC use classifications and this study's water quality sections, is shown in Figure 4. All C classifications in this figure were upgraded in 1978 to Class B. Phosphorus was considered the controlling parameter in the Neponset upstream from its confluence with Mother Brook, and coliform bacteria the controlling parameter downstream from this location. Water quality in the Neponset declines sharply at Mother Brook, which diverts water from the Charles River to the Neponset for flow augmentation purposes. A primary source of pollution of the lower Neponset River thus appears to be the Charles River.

5. POLLUTANT LOADING DISTRIBUTIONS

Current (year 1970) and projected (year 2000) land use and sewerage service distributions were developed for each community in the Boston metropolitan area from data contained in the EMMA report and other relevant sources. These community distributions were then apportioned among the 19 water quality sections in the Boston area in direct proportion to the fraction of total individual community acreages tributary to each of the respective water quality sections. Sewered populations were divided among separate, combined, and unsewered services. Sewered areas, for each service type, were divided among residential, commercial, industrial, and "other" land uses. Nonpoint source areas were divided into agriculture, forest, wetlands, mining/disposal and recreation land uses. Aggregated pollutant loading distributions for each of the 19 water quality sections were computed by multiplying each land use area by an estimated annual average pollutant loading factor for the respective land use.

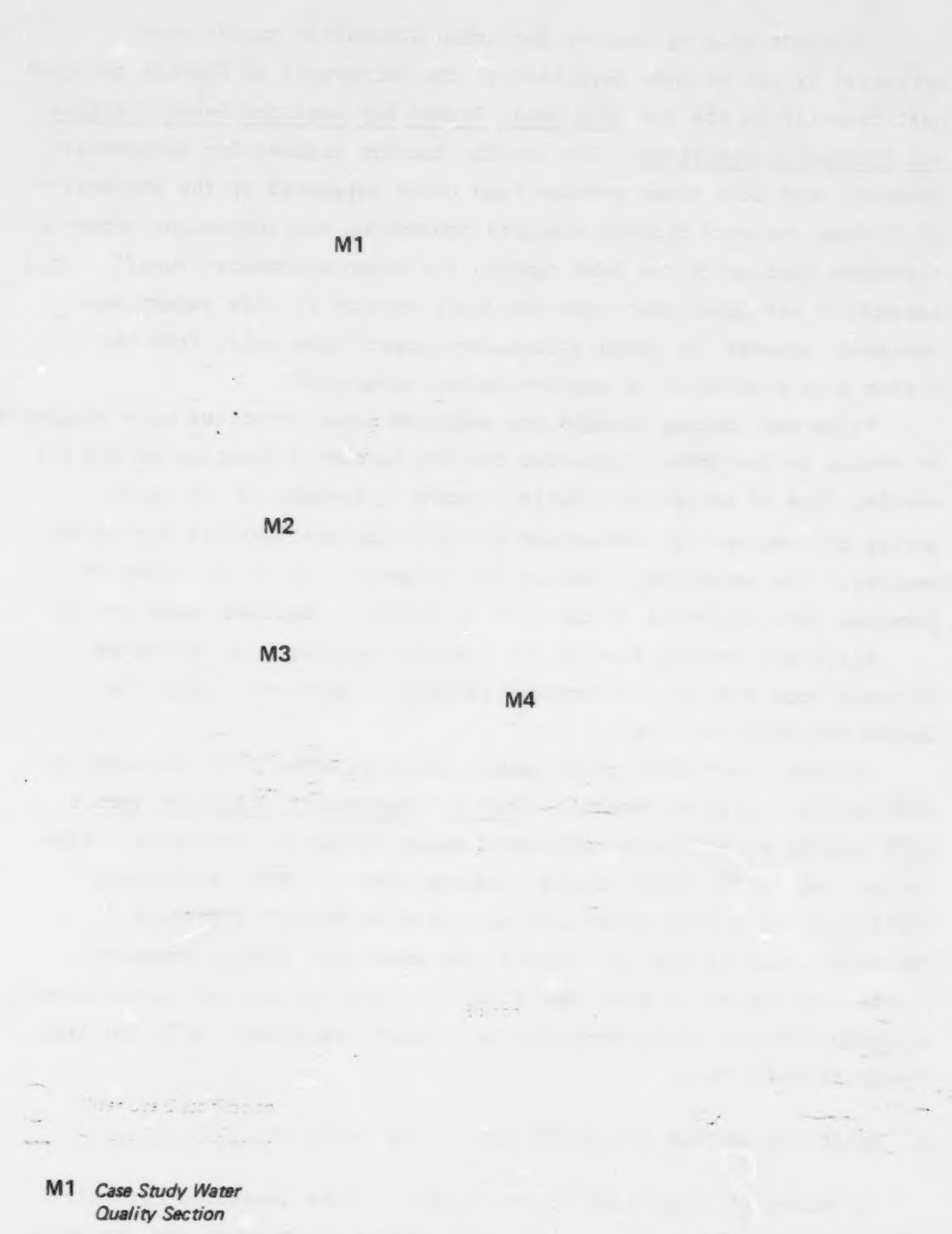
M1
M2
M3
M4
M1 Case Study Water Quality Section

Figure 3 Mystic River Basin

Pollutant loading factors for urban stormwater runoff were estimated by the methods developed at the University of Florida and used most recently in the EPA 1978 Needs Survey for Combined Sewer Overflow and Stormwater Discharge. The loading factors assumed for phosphorus, however, were five times greater than those suggested by the University of Florida, to more closely simulate phosphorus concentrations reported elsewhere (including the EMMA report) for urban stormwater runoff. This assumption was questioned when the draft version of this report was reviewed; however, no urban stormwater quality data exist from the Boston area with which to confirm either assumption.

Pollutant loading factors for combined sewer overflows were estimated by adding to the urban stormwater loading factors a fraction of the dry weather flow of sewage pollutants assumed to deposit in the sewers during dry weather for subsequent resuspension and overflow during wet weather. The depositing fraction was assumed to be 0.108, based on previous data collected on the City of Boston's combined sewer system.

Pollutant loading factors for nonpoint sources were estimated entirely from available literature values; no data exist from the Boston metropolitan area.

Current (year 1970) point source loadings were those tabulated by DWPC in the series of reports: Part B - Wastewater Discharge Data, 1975, published by the Massachusetts Water Resources Commission. Projected (year 2000) point source loadings from all EMMA recommended facilities and alternatives were developed by Kennedy Engineers. Projected loadings from peripheral area municipal sewage treatment plants were estimated from EMMA study flow projections and conventionally accepted effluent characteristics of primary, secondary, AWT, and land treatment facilities.

6. RELATIONS BETWEEN POLLUTION SOURCES AND WATER QUALITY

A number of simplified empirical models were developed for this analysis to relate water quality measurements to observed and estimated pollution sources and then to project the relative impacts of alternative pollution abatement strategies on future water quality in the Boston metropolitan area.

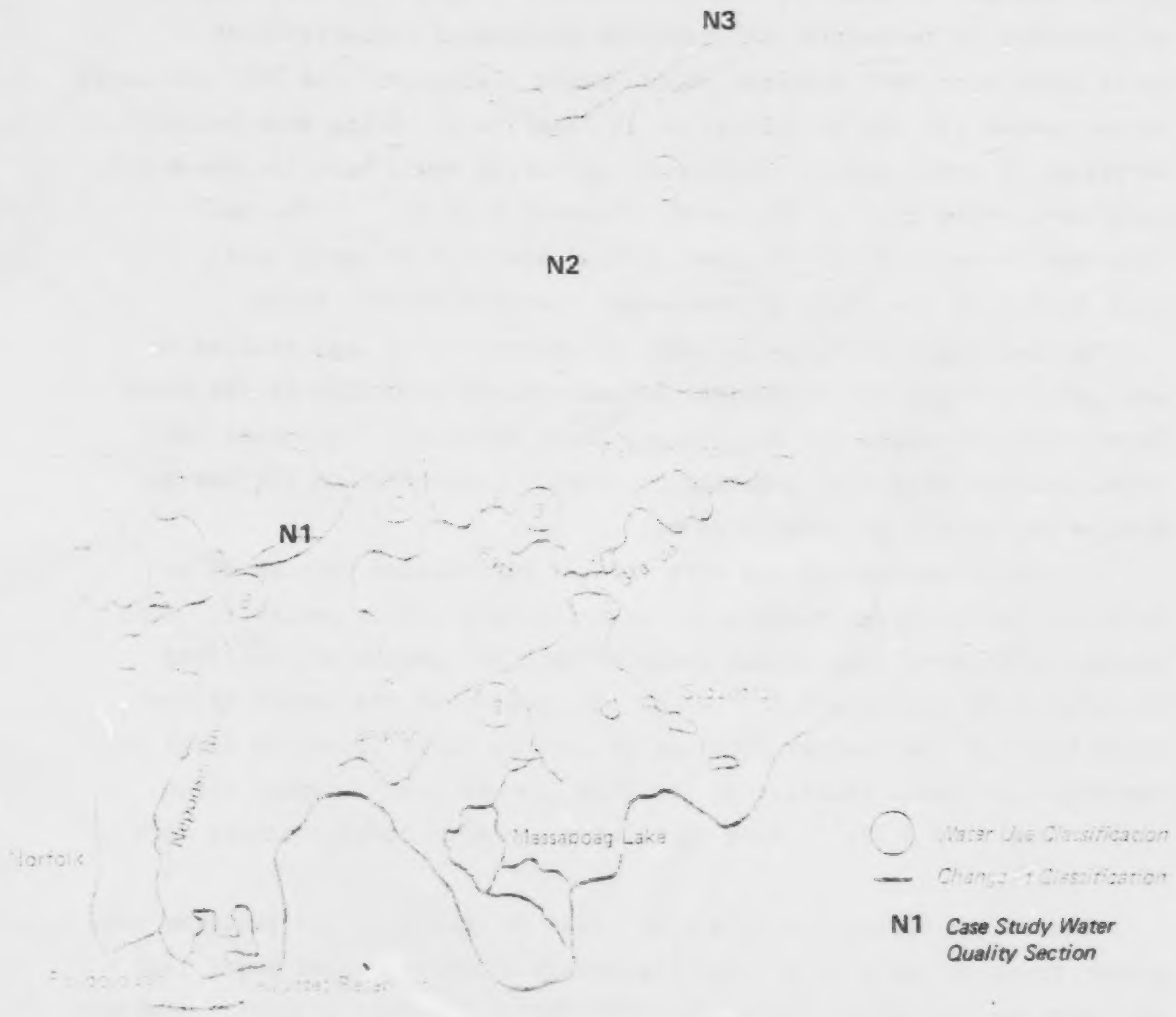
N3
N2
N1
Massapoag Lake
Norfolk
Neponset R.
Water Use Classification
Change in Classification
N1 Case Study Water Quality Section

Figure 4 Neponset River Basin

Phosphorus was modeled as the limiting nutrient in the upper and middle Charles River. This model considered diffuse stormwater runoff and nonpoint sources, as well as point source loadings. Phosphorus was considered to decay exponentially with a decay rate constant of 0.1 day^{-1} (base e). Flow rates and travel times along the Charles were estimated from the Massachusetts STREAM model for the Charles River. This phosphorus model did not well represent observed upstream concentrations in the vicinity of existing sewage treatment plants. It was, indeed, not possible to reconcile DWPC reported phosphorus concentrations in these areas with DWPC reported point source discharges (the DWPC discharge values seemed too low by factors of at least two). Using more believable estimates of point source phosphorus discharges would have increased the phosphorus decay rate in this model to about 0.25 day^{-1}. The more conservative version was retained in this analysis as being more consistent with the "lack of knowledge" concerns of Sec. 303(d).

Maximum algal biomass, in terms of chlorophyll-a, was related to available nitrogen and phosphorus concentrations according to the Monad formulation developed for the Potomac River estuary. This model indicated that the generally limiting phosphorus concentration for Boston area waters should be about 0.05 mg/l.

A greatly simplified and more readily generalized version of an existing Charles River Basin model was adapted for this analysis. This version considered exponential decay of both phosphorus and coliform concentrations throughout the basin. It considered the impact of both stratification and destratification on surface water detention times in the basin and basin salinity on coliform die-off coefficients, which varied from 1 to 5 day^{-1} (base e) between seawater concentrations from 0% to 100%.

The Boston Harbor coliform model used in this analysis followed the linear transfer logic of an existing steady-state segmented model that was developed by Hydroscience, Inc. for DWPC. For this analysis, transfer coefficients for this model, describing the water quality impact in one segment from a pollution load in any other segment, were developed entirely empirically. This model, ultimately expressed as a simple set of simultaneous linear equations, requires for its calibration a number of different pollutant loading conditions and water quality observations for each water quality segment equal to the total number of segments. In view of the commonly observed reluctance of water quality planners to collect the data appropriate to the problem they are attempting to solve, it is argued here that any analytical approach that demands the correction of this problem must have intrinsic merit.

7. ALTERNATIVE POLLUTION CONTROL TECHNOLOGIES

The list of pollution control technologies examined for this study was by no means intended to be exhaustive; rather, it was intended to be representative of the array of tools available to a water quality management planner (in contrast, the EMMA study was limited to a few and largely inappropriate technologies). Conventional, and less conventional, structural alternatives as well as examples of nonstructural alternatives were examined in this study.

Pollution control technologies for continuous point source discharges are conventionally categorized as primary, secondary, tertiary or advanced waste treatment (AWT), and land application, in generally ascending order of pollutant removal efficiencies. A summary of effluent characteristics common for these control technologies follows.

	Treatment Technology			
Pollutant	Primary	Secondary	AWT	Land
Biochemical oxygen demand (mg/l)	120	30	5	3
Suspended solids (mg/l)	120	30	5	7
Nitrogen (mg/l)	30	25	20	3
Phosphorus (mg/l)	10	5	1	0.05
Total coliforms/100 ml				
Unchlorinated	10^6	10^4	200	negl.
Chlorinated	1,000*	1,000	negl.	negl.

---

*Cum grano salis.

Nonstructural alternatives available for reducing wastewater flows and/or pollutant loadings include: elimination of excess infiltration and inflow, implementation of water conserving devices and policies, prohibition of household garbage grinders, and greater reliance on on-site disposal systems.

Intermittent discharges of urban stormwater, raw sewage bypasses and combined sewer overflows constitute the most serious of today's pollution problems in the urban waterways of the United States and receive the least and last attention of the EPA construction grants program. Excessive estimates of the costs of correcting these problems stems in great measure from the erroneous use of the hydrologic "design storm" concept in a pollution control context, as was done in the EMMA study.

Combinations of off line storage and additional wet weather treatment capacity are conventional control technologies for intermittent discharges. The least effective version of this technology is represented by the detention/chlorination facilities constructed in the Boston area for combined sewer overflows, and more of which are assumed in the EMMA Recommended Plan. Alternative technologies include maximizing the available in-line storage capacity of existing sewer systems, as practiced in Seattle and Minneapolis-St. Paul, and automated dry weather flushing of combined sewer systems to prevent the accumulation of pollutant deposits in the flat-grade pipes in those systems. Intensive street cleaning (vacuum) operations, designed to minimize accumulations of water pollutants on streets and other impervious surfaces, offer seemingly economical control alternatives for urban stormwater runoff.

8. ALTERNATIVE CASE STUDY CONTROL STRATEGIES

Three fundamental control strategy categories were examined in this study. All alternatives were based on the Boston area population and land use distributions projected for the year 2000 by the EMMA study. The first category emphasized the repair and rehabilitation of existing facilities, correction of existing infiltration/inflow problems, and limited per capita wastewater flows in accordance with requirements of the 1977 Clean Water Act (PL 95-217). Average study area dry weather flows for the Category I alternatives were 348 mgd, compared to the EMMA projected 586 mgd. Available Boston area wastewater flow data indicated that actual flows, after correction of malfunctioning tide gates and excessive I/I, might be significantly less than the 348 mgd estimated here. The Category I alternatives were as follows.

IA. Baseline upgrading, rehabilitation of existing systems; present MSD service areas only; 1.5 hours detention at Deer (215 mgd) and Nut (115 mgd) Islands.

IB. Expand Deer and Nut Islands primary treatment to 2.0 hours detention time; present MSD service areas only.

IC. Expand MSD service to EMMA projected areas; 2.0 hours detention at Deer (212 mgd) and Nut (136 mgd) Islands.

ID. Add 100 mgd wet weather treatment capacity to Deer Island (312 mgd), with combinations of five different control options for separate storm and combined sewered areas tributary to Deer Island.

1) Retain combined sewer overflows with expanded primary treatment at Deer Island.

2) Automate dry weather flushing of combined sewer deposits, with wet weather in-line storage.

3) Provide storage and separate treatment of stormwater.

4) Provide street cleaning for urban runoff source control.

5) EMMA-recommended detection/chlorination facilities.

IE. Add secondary treatment to Deer and Nut Islands.

Secondary treatment was included in the Category I alternatives for three reasons: EPA Region I has long concentrated on the enforcement of the Sec. 301 (PL 92-500) secondary treatment requirement for the Boston Harbor treatment plants although all available water quality studies indicate the major pollution problems to be elsewhere; the existing primary treatment plants appear to avoid coliform criteria violations only because of effluent chlorination, and the Boston area acceptance of wastewater chlorination as a panacea for complex and serious pollution problems may well be ill-founded. The production of known carcinogens by wastewater chlorination, the increasing evidence of tumors in fish and shellfish exposed to wastewater effluents, the toxicity of chlorine itself to both marine and freshwaster organisms at concentrations prescribed in MDC NPDES permits for combined sewer overflows, and the lack of any correlation between virus and coliform destruction by chlorination of poorly treated wastewaters all dictate a serious re-examination of the appropriateness of prevelant wastewater chlorination assumptions. Secondary treatment, without chlorination, provides a more ensured removal of viruses and other pathogens, as well as the coliform indicator organisms, than the suspect practice of chlorinating poorly treated wastewaters. These chlorination questions apply even more strongly to the existing and EMMA-recommended combined sewer overflow detention/chlorination facilities in the Boston metropolitaan area.

The second category of alternatives was the MDC's complete EMMA Recommended Plan (Alternative IIA), and with some treatment plant modifications suggested by Kennedy Engineers (Alternative IIB). The third category consisted of a series of facilities alternatives to the EMMA Recommended Plan. The year 2000 service areas, populations, and wastewater flows and characteristics for all Category II and III alternatives were those of the EMMA Recommended Plan. These alternatives are summarized as follows.

IIA. EMMA Recommended Plan: secondary treatment at Deer (400 mgd) and Nut (150 mgd) Islands; satellite AWT in middle Charles (31 mgd) and upper Neponset (25 mgd) Rivers; detention/chlorination of combined sewer overflows.

IIB. EMMA Recommended Plan with additional modifications and rehabilitation suggested by Kennedy Engineers.

IIIA. EMMA Recommended Plan without satellite AWT plants; Nut Island expanded to 186 mgd.

IIIB. EMMA Recommended Plan with secondary treatment at satellite plants; satellite effluents discharged to Boston Harbor.

IIIC. EMMA Recommended Plan with secondary treatment at satellite plants; satellite effluents discharged to rivers; Mother Brook diversion from Charles to Neponset River eliminated.

IIID. EMMA Recommended Plan with land treatment of satellite flows in middle Charles and upper Neponset Rivers; eliminate Mother Brook diversion.

IIIE. EMMA Recommended Plan with one satellite secondary plant (56 mgd) on Neponset River; effluent discharged to Boston Harbor.

IIIF. EMMA Recommended Plan with one satellite secondary plant (56 mgd) discharging to Neponset River; eliminate Mother Brook diversion.

IIIG. EMMA Recommended Plan with one satellite land treatment facility (56 mgd) on the Neponset River; elmininate Mother Brook diversion.

IIIH. EMMA Recommended Plan with one satellite AWT plant (56 mgd) on Neponset River; eliminate Mother Brook diversion.

IIIJ. EMMA Recommended Plan with primary treatment at Deer (400 mgd) and Nut (186 mgd) Islands; effluents piped to deep ocean disposal; no satellite plants.

IIIK. EMMA Recommended Plan with primary treatment at Deer (400 mgd) and Nut (186 mgd) Islands; effluents discharged to present locations; no satellite plants.

Pollution Loadings and Water Quality Impacts

Alternatives IA, IB, and IC primarily affect five water quality sections: the Charles River Basin (C7 and C8), the Mystic River (M4), Boston Inner Harbor (BH1), and Dorchester Bay (BH2). These sections are controlled largely by combined sewer overflows. The additional wet weather carrying capacities in the existing combined sewer systems, which would result from the lower dry weather flows in these alternatives, would reduce projected (year 2000) street surface and pipe deposition loadings from combined areas by 41% and 58%, respectively. After comparisons of the Alternative ID options, intensive street cleaning (ID.4) was selected as the most cost-effective single option for urban stormwater control, and automated sewer flushing with in-line storage (ID.2) for control of combined sewer overflows. The street cleaning performance objective throughout most of the Boston metropolitan area was 95% removal of phosphorus and coliform bacteria. Different assumptions about phosphorus loadings and decay rates in receiving waters could have reduced this performance requirement to about 75%. Sewer flushing systems necessary to satisfy water quality criteria were estimated to require 70% to 98% pollutant deposition reductions, depending on overflow locations. In the upper Charles River, peripheral AWT plants now proposed or under construction will have to be converted to land application if water quality criteria in this area is to be satisfied. Streamflows in the Charles, Mystic, and Neponset Rivers are simply not large enough to assimilate effluents from a secondary or AWT facility of any magnitude.

One of the principal difficulties with the EMMA Recommended Plan (Category II) is that the year 2000 wastewater flows projected by EMMA would not allow any excess interceptor capacities for emptying the proposed (or existing) combined sewer detention/chlorination facilities. The only treatment of combined sewer overflows would be chlorination. Dorchester Bay (BH2), Quincy Bay (BH3), and Boston Outer Harbor (BH4) would be the only locations satisfying water quality criteria. If the chlorination practice is seriously questioned, there would be no acceptable water quality at any location in the Boston metropolitan area. Water quality at every location in the Charles and Neponset Rivers downstream from the EMMA-recommended satellite AWT plants would be further degraded because of excessive phosphorus concentrations.

All of the Category III alternatives suffer from the same combined sewer overflow problems of Category II because all include the same wastewater flows and inadequate detention/chlorination facilities that are contained in the EMMA Recommended Plan. Water quality in the Neponset River and in the Charles River above Watertown could become acceptable (swimming/fishing) if the intensive street cleaning operations from Category I were adopted in these areas and all point source effluents were either converted to land treatment (Alternatives IIID or G) or exported out of the basins (Alternatives IIIA, B, E, J, or K). To the extent that Neponset River water quality is superior to that in the Charles River, the present Mother Brook diversion acts to further degrade water quality in the Neponset.

9. WATER QUALITY BENEFITS OF ALTERNATIVE INVESTMENT STRATEGIES

Section 303(d) of PL 92-500 requires that each state establish a priority ranking system for water quality limited stream segments, "taking into account the severity of the pollution and the uses to be made of such waters." (Emphasis added.) The priority ranking system included in Massachusetts basin plans is heavily weighted toward severity of pollution at the expense of potential water uses. Construction grant priorities have, in any case, been influenced more by the applicants' willingness-to-proceed than by either severity of pollution or potential water use. An alternative priority ranking system, weighted more evenly toward potential water use, was developed during this case study. The water use potential portion of this ranking system was a population distribution model based on the relative distances between census tract populations and all possible locations of acceptable quality waters. Relative use, or benefit, potentials for clean water at each of the 19 Boston area water quality sections were developed by multiplying each section's respective user population distribution by local annual willingness to pay estimates for swimming/fishing quality waters ($42.85 per capita). Relative pollution severities in each section were considered to be represented by the costs of correction of that section's pollution sources. The resulting priority ranking system was, thus, based on a conventional benefit/cost analysis. Benefits of clean water were represented by public expressions of willingness to pay for clean water, and costs were simply those proposed for achieving clean water. For this case study, benefits and costs were both consistently compared on a present worth basis, in accordance with EPA Cost Effectiveness Analysis Guidelines (Appendix A, 40CFR, Part 35, Subpart E). Construction and implementation schedules, and resulting water quality improvements, were in accord with the EMMA-recommended construction staging schedule.

In this investment strategy analysis, the Category I alternatives were arranged into three different investment sequences. Sequence I.1 considered the present MSD service area only, with maximum Boston area stormwater and combined sewer overflow pollution control, Alternatives ID.2 and 4a-d. Alternative ID options 4a through 4d are urban street cleaning operations along the Charles River Basin, Mystic River, and Boston Inner Harbor (ID.4a); along the middle Charles River (ID.4b); the Neponset River (ID.4c); and then the upper Charles River (ID.4d). Investment sequence I.2 includes the same extensive stormwater and combined sewer overflow control options but expands the MSD service area to that projected by the EMMA Recommended Plan. Sequence I.3 also includes the EMMA projected service area and substitutes the EMMA-recommended detention/chlorination facilities for the sewer flushing and extensive street cleaning programs of Sequences I.1 and I.2. All three investment sequences include secondary treatment (Alternative IE) for Deer and Nut Islands effluents. It should be noted also that all Category I investment sequences assume the conversion of peripheral area point source discharges along the upper Charles and Neponset Rivers to land treatment.

All of the pollution control or investment strategy alternatives examined in this analysis are compared in Table 2 on the basis of present value costs, water quality benefits, and benefit/cost ratios. The EMMA Recommended Plan can be seen to have the lowest benefit/cost ratio of any of the alternatives examined, primarily because the plan would produce so few water quality benefits. Only three water quality sections, all in Boston Harbor, would be significantly improved by the EMMA Recommended Plan, and these projected improvements result primarily from discontinuing the present sewage sludge discharges to the harbor.

TABLE 2

WATER QUALITY BENEFIT/COST ANALYSIS OF ALTERNATIVE INVESTMENT STRATEGIES

	Alternatives	Present Worth Costs ($ millions)	Conditions with Effluent Chlorination		
			Acceptable Water Quality Sections	Present Worth Benefits ($ millions)	Benefit/Cost Ratio
	Sequence 1, A, B, D.2 & 4a-d	457.0	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.97
	with E.1, secondary treatment	607.1	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.73
	Sequence 2, A, B, C, D.2 & 4a-d	487.2	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.91
	with E.2, secondary treatment	641.4	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.69
	Sequence 3, A, B, C, D.5 (EMMA)	454.3	BH1-BH4	107.2	0.24
	with E.2, secondary treatment	608.5	BH1-BH4	107.2	0.18
A.	EMMA Recommended Plan	603.0	BH2-BH4	84.8	0.14
B.	EMMA with STP additions	653.3	BH2-BH4	84.8	0.13
A.	No satellite plants	582.4	BH2-BH4	84.8	0.15
B.	Two secondary satellites, effl. to B.H.	581.2	BH2-BH4	84.8	0.15
C.	Two secondary satellites, effl. to rivers	563.0	BH2-BH4	84.8	0.15
D.1	Two land treatment satellites	576.1	BH2-BH4	84.8	0.15
D.2	With ID.4b-d, street cleaning	670.3	C1-C6, N2, N3, BH2-BH4	262.0	0.39
D.3	With land at upstream locations	670.3	C1-C6, N1-N3, BH2-BH4	283.8	0.42
E.	One secondary satellite, effl. to B.H.	575.8	BH2-BH4	84.8	0.15
F.	One secondary satellite, effl. to Nep.	564.1	BH2-BH4	84.8	0.15
G.1	One land treatment satellite on Nep.	582.7	N3, BH2-BH4	108.3	0.19
G.2	With land at upstream location	582.7	N1-N3, BH2-BH4	163.9	0.28
H.	One AWT satellite on Neponset River	597.6	BH2-BH4	84.8	0.14
J.	Primary treatment, effl. to ocean	475.7	BH2-BH4	84.8	0.18
K.	Primary treatment, effl. to Harbor	390.9	BH2-BH4	84.8	0.22

The maximum stormwater and combined sewer overflow control sequences provide the highest benefit/cost ratios.

Water quality benefits were estimated, in Table 2, with the assumptions that the present Boston area wastewater chlorination practices will be continued through the year 2000 and that these practices will continue to be acceptable through the year 2000. The Boston Harbor water quality improvements projected to result from the EMMA Recommended Plan, for example, depend on the assumption that the EMMA detention/chlorination facilities will reduce coliforms (and pathogens) by 90% and will produce no additionally unacceptable environmental hazards. If this assumption is unwarranted, and it is argued in this analysis that it is, the EMMA Recommended Plan would produce no water quality benefits anywhere in the Boston metropolitan area.

The same investment strategy comparisons are presented in Table 3, with the assumption that the wastewater chlorination practice will be either discontinued or its effectiveness discounted as better information becomes available in the next two decades. The distinctions among alternatives become much sharper with this assumption. The EMMA Recommended Plan, and most of the Category III alternatives, provide zero water quality benefits in the absence of chlorination or its assumed effectiveness. Only the Neponset River land treatment alternative (IIIG) would provide any benefits; adding the intensive street cleaning option (ID.4 b-d) to Alternative IIID would provide additional benefits in the upper Charles River but only if all upstream point source discharges were also converted to land treatment facilities. Boston Harbor Sections BH3 and BH4 would become acceptable after secondary treatment, and even under Alternative IIIJ, if not for the fact that the EMMA wastewater flow projections result in no "treatment" of combined sewer overflows other than chlorination.

10. POLICY IMPLICATIONS

The implications of this analysis for national water quality management policies are several. First, and most important, there seems within the pollution control infrastructure to be a dedication to maintaining

TABLE 3

WATER QUALITY BENEFIT/COST ANALYSIS OF ALTERNATIVE INVESTMENT STRATEGIES

	Alternatives	Present Worth Costs ($ millions)	Conditions without Effluent Chlorination		
			Acceptable Water Quality Sections	Present Worth Benefits ($ millions)	Benefit/Cost Ratio
	Sequence 1, A, B, D.2 & 4a-d	457.0	C1-C8, N1-N3, M4	328.3	0.72
	with E.1, secondary treatment	607.1	C1-C8, N1-N3, M4, BH1-BH4	408.2	0.67
	Sequence 2, A, B, C, D.2 & 4a-d	487.2	C1-C8, N1-N3, M4	328.3	0.67
	with E.2, secondary treatment	641.4	C1-C8, N1-N3, M4, BH1-BH4	408.2	0.64
	Sequence 3, A, B, C, D.5(EMMA)	454.3	None	0	0
	with E.2, secondary treatment	608.5	BH1-BH4	55.9	0.09
A.	EMMA Recommended Plan	603.0	None	0	0
B.	EMMA with STP additions	653.3	None	0	0
A.	No satellite plants	582.4	None	0	0
B.	Two secondary satellites, effl. to B.H.	581.2	None	0	0
C.	Two secondary satellites, effl. to rivers	563.0	None	0	0
D.1	Two land treatment satellites	576.1	None	0	0
D.2	With ID.4b-d, street cleaning	670.3	C1-C6, N2, N3	177.2	0.26
D.3	With land at upstream locations	670.3	C1-C6, N1-N3	199.0	0.30
E.	One secondary satellite, effl. to B.H.	575.8	None	0	0
F.	One secondary satellite, effl. to Nep.	564.1	None	0	0
G.1	One land treatment satellite on Nep.	582.7	N3	23.5	0.04
G.2	With land at upstream location	582.7	N1-N3	79.0	0.14
H.	One AWT satellite on Neponset River	597.6	None	0	0
J.	Primary treatment, effl. to ocean	475.7	None	0	0
K.	Primary treatment, effl. to Harbor	390.9	None	0	0

a high level of ignorance about natural waters and the way they respond to waste loads. Despite the universal recognition that combined sewer overflows and urban stormwater runoff are the major sources of pollution of Boston area waters, not a sample of either source was collected or examined for the EMMA study. No effort was made to quantify either pollution source nor to relate those or any other sources in any predictive fashion to the specific water quality problems they cause. The EMMA planning decisions were plainly not based on any water quality objectives or considerations but on questionable estimates of sewage conveyance requirements. The EMMA planning alternatives were simply alternative sites for a single preselected alternative - more and larger pipes, detention tanks, and treatment plants. The one section of PL 92-500 that clearly delineates the essential series of steps constituting a systematic and comprehensive water quality management planning process - Section 303 - seems so far to have been overlooked in the Boston area. An affirmative insistence on rigorous compliance with all the provisions of this section, particularly the scientific adequacy of each compliance step, may present a technical or administrative challenge but its critical importance to the water quality objective of PL 92-500 simply cannot be overstated. Without this insistence, that objective will not be achieved; with it, the EMMA Recommended Plan might never have arrived at its present form.

Second, a greater emphasis on maximizing and upgrading the performance of existing sewerage systems (and investments) before constructing new facilities should be encouraged. The wastewater flow restrictions adopted in the 1977 Clean Water Act (PL 95-217) is a significant step in this direction. More clear EPA guidelines for correction of infiltration (including malfunctioning tide gates) in combined sewer systems would be additionally helpful. Correction costs should be compared with costs of additional wet weather control facilities, or costs of additional sewers necessary to make up for wet weather capacities occupied by infiltration in existing sewers. The present comparisons between correction costs and additional dry weather treatment capacities is simply wrong for combined sewer systems. The impact of large scale regional sewerage systems, with uncontrolled I/I and extra-basin water transfers, on future regional water supplies should be included in the cost-effectiveness analysis process. Regionalization of wastewater management in general should be seriously reassessed if not actively discouraged by EPA.

Third, the control alternatives examined in this study for combined sewer overflows and urban stormwater runoff need to be demonstrated on a large scale and fairly soon. The Alternative and Innovative Technologies provisions of PL 95-217 now provide the necessary incentives for such demonstrations for combined sewer systems. The elimination, by PL 95-217, of separate stormwater runoff from grant eligibility, however, seems to be a step backwards. Participation by EPA in the operation and maintenance costs of pollution control systems would also encourage, if only psychologically, further development of the kinds of Category I control alternatives examined in this study.

Finally, but by no means least in importance, the policy of chlorinating combined sewer overflows, and other wastewaters as well, needs to be seriously re-examined. Questions regarding the continued acceptance of this policy assume particular significance in light of the secondary treatment waiver provisions of PL 95-217.

11. EPILOGUE: AGENCY AND PUBLIC REVIEW AND COMMENTS

Draft copies of the Boston Case Study report were distributed publicly for review and comment, and meetings were held with involved agencies and the public in the early fall of 1978. Written comments were obtained by the Federal Interagency Study Team and distributed to the four case study contractors for their consideration and response. Comments to this report were voluminous. They were grouped into three general categories: situational changes since the case study's completion, policy considerations, and specific technical questions and comments.

In the first category, nearly all agency respondents argued that the EMMA Recommended Plan was not going to be automatically or unquestioningly implemented, indeed that no intentions or commitments to do so had ever existed. EPA Region I's EIS for portions of the EMMA Recommended Plan had already concluded that the AWT satellite plants would not be acceptable, for water quality reasons, and the EMMA combined sewer overflow recommendations were undergoing extensive re-evaluation in the 201 facilities planning process. The Massachusetts' revision of water quality standards in 1978 was noted in several comments. Predictions in this report that an EPA-sponsored destratification project in the Charles River Basin would further degrade water quality and result in excessive atmospheric H_2S concentrations were described by EPA Region I as erroneous because the destratification project had operated successfully throughout the summer of 1978. (Subsequent investigation found that the destratification project has not of this date been activated in the stratified area of the basin.) The failure of this report to acknowledge the impact of PL 95-217 on the water quality management process was noted (and has been corrected). In response, it is noted here that the waters of highest use potential in metropolitan Boston are still classified C; the 303(d) segmentation system still erroneously classifies the Charles River Basin and all of Boston Harbor as "effluent limited"; the EMMA Recommended Plan is still the accepted 303(e) Water Quality Management Plan for Boston Harbor and tributaries; there is still no plan for management of urban stormwater runoff in metropolitan Boston; Massachusetts 1978 Water Quality Standards remain confusing although for somewhat different reasons than in 1974; and another year has passed with no water quality improvements in the Boston metropolitan area.

In the second category, most public comments supported observations in this report of the failures of the Sec. 303 planning process; agency comments complained of time and resource limitations. Effectiveness assumed in this report for street cleaning and sewer flushing was questioned in agency comments although further examination and demonstrations of these technologies was supported. The chlorination issue raised in this report, and its significance to the secondary treatment question, was acknowledged in EPA comments but not accepted in state agency comments. Agency comments on wastewater flows, flow projections, and sewer capacities indicated some confusion in these agencies about what actually happens in the Boston area sewerage systems, as well as the assumptions in the EMMA Recommended Plan. The EPA questioned this report's suggested participation in O&M costs; Massachusetts DWPC supported it. Some EPA Region I comments questioned the water quality benefits analysis used in this study; others supported it.

The third category consisted of specific comments and criticisms of the technical and cost assumptions and the models used in this report for water quality projections, street cleaning and sewer flushing effectiveness, and land treatment. Comments about phosphorus loadings sources and water quality responses were particularly well-taken. There are (or were during this study) no stormwater quantity or quality data from the Boston area and there are clear discrepancies between available water quality data and the limited point source discharge data for Boston area rivers. Better (or even some) data might well have resulted in different modeling assumptions. It is not, however, likely that the results or conclusions in this report would have been qualitatively different. Boston Harbor tributary rivers would still be too small to assimilate wastewater effluents from any treatment plants other than land treatment facilities; extensive control, whether 95% or 75% pollutant removals, of combined sewer overflows and urban stormwater runoff would still be necessary to achieve swimming/fishing water quality objectives.

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LIST OF ABBREVIATIONS

AD	antidegradation
APWA	American Public Works Association
AWT	Advanced Waste Treatment
BOD	Biochemical Oxygen Demand
BPT	Best Practicable Treatment
COE	Army Corps of Engineers
CEQ	Council on Environmental Quality
DWPC	Massachusetts Division of Water Pollution Control
EF	effluent limited
EMMA	Eastern Massachusetts Metropolitan Area
EPA	United States Environmental Protection Agency
FWPCA	Federal Water Pollution Control Administration
gpcd	gallons per capita per day
JTU	Jackson Turbidity Units
LUcor	land use area corrections
MAPC	Metropolitan Area Planning Council
mcf	millions of cubic feet
MDC	Metropolitan District Commission
mgd	millions of gallons per day
MPN	most probable number
MSD	Metropolitan Sewerage District
N	nitrogen
NPDES	National Pollutant Discharge Elimination System
NSF	National Science Foundation
O&M	Operations and Maintenance
OMB	Office of Management and Budget
P	phosphorus
SS	suspended solids
USGS	United States Geological Survey
WQ	water quality limited

LIST OF ABBREVIATIONS

AD	antidegradation
APWA	American Public Works Association
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gpcd	gallons per capita per day
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LUcor	land use area corrections
MAPC	Metropolitan Area Planning Council
mcf	millions of cubic feet
MDC	Metropolitan District Commission
mgd	millions of gallons per day
MPN	most probable number
MSD	Metropolitan Sewerage District
N	nitrogen
NPDES	National Pollutant Discharge Elimination System
NSF	National Science Foundation
O&M	Operations and Maintenance
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P	phosphorus
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1. OVERVIEW AND SUMMARY

1.1 Introduction

This analysis of Water Quality Goals, Objectives, and Alternatives in the Boston Metropolitan Area was undertaken as part of the overall Boston Case Study of the Clean Water Grant Program that is administered by the United States Environmental Protection Agency under the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). The Boston Case Study is being conducted by a federal interagency study team composed of representatives from:

- the Office of Management and Budget (OMB);
- the National Science Foundation (NSF);
- the Council on Environmental Quality (CEQ) and
- the Environmental Protection Agency (EPA).

The purpose of this Boston Case Study is to document and evaluate the decision-making process in the administration of the Clean Water Grant Program in the Boston Metropolitan Area. The Case Study has been conducted in two phases. Phase I, intended as a brief overview to identify significant issues and problems for more detailed analysis, was completed in the summer of 1976. Consultants participating in the Phase I studies were:

- Kennedy Engineers, Inc., San Francisco, consultant to NSF for Facilities Engineering;
- Resource Applications, Inc., Cambridge, MA, consultant to CEQ on Water Quality Objectives;
- Vertex Corp. McLean, VA, consultant to NSF for Water Quality Objectives and
- Urban Systems Research & Engineering, Inc., consultant to CEQ for Institutional Analysis.

The more detailed Phase II analyses have involved:

- Kennedy Engineers, Inc., San Francisco, consultant to NSF for Facilities Engineering;
- Urban Systems Research & Engineering, Inc., Cambridge, MA, consultant to CEQ for Financial and Institutional Analyses;
- Environmental Research & Technology, Inc., Concord, MA, consultant to NSF for Sludge Management Policies Analysis and
- Environmental Research & Technology, Inc., Concord, MA, consultant to CEQ for Water Quality Goals, Objectives, and Alternatives.

The specific concerns of this analysis of Water Quality Goals, Objectives, and Alternatives have been the technical (scientific) adequacy of the decision-making process, the probable impacts of that process on future water quality and the likelihood of achieving in the Boston Metropolitan Area the mandated national goal of swimmable/fishable waters. Where feasible, the analysis has been concerned with alternatives not included in the Boston area planning process but which appear to offer significant water quality advantages. It was intended that this analysis would result in the identification of water quality management issues of national, as well as local, significance. The major findings of the analysis are summarized briefly below.

Water quality in the Boston Metropolitan Area, with two exceptions, is inadequate to support swimming or fishing activities anywhere. In the Charles River Basin, water quality does not even satisfy the Massachusetts criteria for recreational boating, although that is a primary use of the Basin at present. The two exceptions to the inadequate Boston area water quality are the waters of Quincy Bay and the northern part of Dorchester Bay in Boston Harbor. Water quality criteria for swimming are satisfied in Quincy Bay, but the unrestricted shellfishing criteria in the area classified for this use are not. Swimming quality criteria have been satisfied at the northern Dorchester Bay beach areas in recent years as a result of the repair and replacement of tide gates in tributary sewer systems.

Summer flows in the upstream reaches of Boston Harbor tributaries are too small to accommodate the discharges from either existing or proposed sewage treatment plants. The highly urbanized lower reaches of these rivers are the recipients of overflows from metropolitan combined sewer overflows, as is the Boston Harbor waterfront. Urban stormwater runoff is a principal and unaddressed source of pollution of Boston area waters everywhere.

The water quality planning process in the Boston Metropolitan Area contained discrepancies from its beginning, since quality criteria for the state's use classes were vague, tautological, and unenforceable. Reclassifications of waters, required by the Act, have not taken place. Criteria for the parameters most important for Boston area waters - dissolved oxygen, nutrients and coliform bacteria - were either relaxed or eliminated in the 1974 modifications of the Standards. Alternative criteria were developed by this analysis.

The water quality impacts of existing and proposed wastewater management facilities in the Boston area were examined in this analysis. Kennedy Engineers, Inc. has analyzed the pollution control performance of these facilities in considerable detail. Alternative facilities and water quality management strategies that offer greater water quality benefits and lower costs than those that have been proposed were developed by this analysis.

The present $855 million Wastewater Management Plan for Boston Harbor-Eastern Massachusetts Metropolitan Area (EMMA) will satisfy swimming/fishing quality criteria in Quincy Bay, Dorchester Bay and Boston Outer Harbor, and at no other location in the Boston Metropolitan Area. If the local assumptions about the efficacy of chlorinating raw sewage overflows were discounted, water quality would not be acceptable at a single location.

The EMMA Recommended Plan will satisfy the national goal of swimmable/fishable waters in so few locations because it was never designed as a water quality management plan; it was designed as a wastewater management plan. It was accepted as the 303(e) Water Quality Management Plan for Boston Harbor and tributaries only after its completion. It lacks the fundamental requirements for water quality management planning delineated in Section 303 of the Act, for example, the total maximum daily loads of pollutants necessary to implement the applicable water quality standards.

Why this should or could have occurred is more properly the subject of an institutional analysis. This study finds the purely technical impact of implementing the EMMA Recommended Plan, however, to be that an expenditure of over a billion dollars will act to foreclose for the remainder of this century any opportunity for swimmable/fishable waters in the Charles, Mystic and Neponset Rivers and the Boston Inner Harbor.

1.2 Historical Perspective*

Concern in the Boston area about water quality, particularly its sanitary significance and close relationship to public sewer systems, is documented at least as far back as 1850, when Lemuel Shattuck completed his Report of the Sanitary Commission of Massachusetts. Shattuck's report coincided with a series of studies in London by Sir Edwin Chadwick recommending the use of tile sewers and separate sewer systems,** and these two men became generally credited with the origins of "The Great Sanitary Awakening" in the United States and England. By 1877, construction of the Boston Main Drainage System had begun, in response to the local water quality conditions of the time, whereby "large (surrounding) territories were at once, and frequently, enveloped in an atmosphere of stench so strong as to arouse the sleeping, terrify the weak, and nauseate and exasperate everybody" (Clarke 1885). This system was completed by 1884; its primary function was to intercept the dry weather raw sewage (and a small amount of stormwater) discharges to local waterways and the Boston Harbor waterfront and to transport them to Moon Island for detention and subsequent release to the Harbor during ebb tides. The 1884 Boston Main Drainage System was a combined system and made no attempt to collect the wet weather overflows from the City of

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*See the Boston Case Study Phase II Engineering Report by Kennedy Engineers, Inc., for a detailed chronology of historical developments in the Boston area.

**Chadwick's advocacy of separate sewer systems led to a local slogan of the times: "the rain to the river and the sewage to the soil" (Fair and Geyer 1958, p. 6).

Boston; these overflows have continued through today. The original 1884 system was, however, designed to be periodically flushed, to prevent the accumulation of pollutants in the system during the dry weather low-flow periods. Large manually-operated valves were placed every half-mile in the low-lying flat-grade sewers for this purpose (Clarke 1885).

By 1905, construction of much of the plumbing for the present Metropolitan Sewerage District (MSD) had been completed. The North Metropolitan Sewerage System collected sewage from north of the Charles River and pumped it to Deer Island for screening and discharge to Boston Harbor. The South Metropolitan Sewerage System collected sewage from parts of the Charles River Valley, the Neponset River Valley and adjacent areas south of the Boston Main Drainage System and conveyed it to Nut Island for screening before discharge to Boston Harbor. In 1906, the taking of shellfish from some areas within Boston Harbor was prohibited because of polluted water. In 1907, the Massachusetts Legislature directed the City of Boston to spend 0.05% of its taxable valuation on separation of its combined sewers to reduce the frequent pollution of the Boston area waters by combined sewer overflows (Chapter 485, Acts of 1907).

Construction of the present Charles River Dam at Leverett Street in Boston was completed in 1910. It was designed to prevent tidal flooding of low-lying sewers along the Charles River estuary, to create a constant level recreational basin and to cover the unsightly and foul-smelling mud flats that were the recipients of combined sewer overflows from the cities of Boston and Cambridge. Along with the present Charles River Basin, the Leverett Street Dam made a freshwater pond of the Back Bay Fens, an area described by Frederick Law Olmstead in 1881 as: "a pestilential swamp into which the Muddy River and Stony Creek emptied the drainage of thousands of acres of suburban Boston. The Fens oozed in turn into the Charles River tidal basin. Besides being chronic menaces to health, the Fen's sluggish watercourses backed up...." In 1919, the Metropolitan District Commission (MDC) was created to assume the functions of the Metropolitan Parks Commission and the Metropolitan Water and Sewerage Board, which had previously administered the MSD.

In 1936, an investigation was conducted by a special legislative commission comprised of the Massachusetts Commissioners of Public

Health, Public Works and the MDC, and the Boston Commissioners of Health and Public Works. The Report of the Special Commission on the Investigation of the Discharge of Sewage into Boston Harbor and its Tributaries (House Document 1600) found nuisance conditions primarily in the vicinity of the main sewer system outlets in Boston Harbor off Deer, Nut and Moon Islands and at some combined sewer overflow outlets. It was observed that, under certain wind and tide conditions, objectionable floating matter, typical of sewage, floated into several of the area's bathing beaches. Pollution was also documented by studies of wood chips released from outfalls and extensive bacterial analyses of the waters and sediments of Boston Harbor. The 1936 Report of the Special Commission recommended the following actions:

- separation of combined sewers in the Boston and MDC systems to prevent combined sewage overflows;
- MDC to provide devices for measuring sewage entering the Metropolitan Sewerage System and to charge tributary cities and towns according to the amounts of sewage they contribute;
- construction of facilities necessary to prevent surface and stormwater from entering the Boston Main Drainage System and the North and South Metropolitan Sewerage Systems;
- closure of bathing beaches on the Boston Harbor waterfront and its tributaries allowed by appropriate Boards of Health;
- consideration of construction of facilities to treat sewage from the Boston Main Drainage System and the North and South Metropolitan Sewerage Districts before it is discharged to Boston Harbor, and consideration of relocating these outlets, "in the distant future if necessary," to a point near the Graves for disposal of treated sewage and
- consideration of construction of primary sewage treatment plants on Deer, Nut and Moon Islands, with possible addition of sludge incineration at these locations (House Document 1600).

Since 1936, there have been scores of reports, studies and articles written about the water quality conditions and problems in the Boston Metropolitan Area, and plans and programs developed for their alleviation. Some have been gradually put into effect. Construction of the primary treatment plant at Nut Island, first recommended in 1936, was completed in 1952. The primary treatment plant at Deer Island was completed in 1968, 32 years after it was first recommended. The City of Cambridge and the Boston Redevelopment Authority have, in recent years, been separating some of their respective combined sewer collection systems, although the interceptors in both cities are still combined. Combined sewer overflows and stormwater runoff remain the primary sources of pollution of the urban waterways in metropolitan Boston.

A number of approaches to the combined sewer overflow problem, other than sewer separation, have been proposed in the Boston area during the past ten years.

- In 1951, C.E. Maguire, Inc. proposed in a report to the MDC the concept of detention and chlorination of combined sewer overflows (Charles A. Maguire Assoc. 1951).
- In 1967, Camp, Dresser and McKee, Inc. proposed a system of interconnected deep rock tunnels 300 feet beneath the city of Boston to collect overflows from existing combined sewers (Camp, Dresser and McKee, Inc. 1967).
- Beginning in 1969, Process Research, Inc., in a series of proposals and reports, recommended an automated sewer flushing system for combined sewers in the Boston Metropolitan Area (Process Research, Inc. 1969, 1972, 1975).

Camp, Dresser and McKee's deep rock tunnel plan for the city of Boston was similar to the Chicago Deep Tunnel Plan, developed by Harza and Bauer Engineers. The deep tunnel system underneath Boston was to be connected to Deer Island by a main storage tunnel. Overflows would then be screened and chlorinated at Deer Island before their ultimate discharge through a deep ocean outfall. The deep tunnel plan was estimated in 1967 (ENR 1100) to cost $430 million and was never put into effect largely because of this expense. A number of scaled-down versions of this plan were subsequently proposed by Camp, Dresser and McKee to the City of Boston (The Old Harbor Plan) and to the Massachusetts Water Resources Commission (The Tenean-Malibu Beach Plan).

The automated combined sewer flushing systems proposed by Process Research also included in-line storage in its control of combined sewer overflows. The flushing approach was based on the long record of observations from many U.S. cities that most of the pollutants in combined sewer overflows were the result of deposition and accumulation in the sewers during the dry weather period antecedent to the storm event. The flushing system was to be designed to prevent this accumulation, thereby upgrading significantly the quality of the overflows. In-line storage was intended to reduce further the volumes and frequencies of the overflows. The estimated costs of this approach were less than 10% of those of other alternatives examined. The approach was not adopted because of its apparent complexity (it required computers, automation, large numbers of flushing stations, etc.) and its requirement for sewer system operation and maintenance beyond what has been traditional in the Boston area.

In 1970, construction was completed by the MDC on the combined sewer overflow detention/chlorination facility at the Cottage Farm Bridge on the Cambridge shore of the Charles River Basin. This facility, originally proposed some 20 years earlier by C.E. Maguire, Inc. and partially funded with an EPA stormwater demonstration grant, was designed to temporarily detain and chlorinate a portion of the overflows from Cambridge before their discharge to the Charles River Basin. Depending upon the intensity and duration of the rainfall event, overflows would be either completely contained, receive some degree of screening, sedimentation and chlorination, or bypass the facility and continue to the Charles River as before. During the 5-year frequency storm for which the facility was designed, the detention and chlorination time for overflows passing through the Cottage Farm facility is seven minutes. Monitoring of the Charles River upstream and downstream of this facility since 1970 has failed to reveal any measurable impact of the facility on water quality in the Charles (MDC 1976; Process Research 1972, 1975, 1976; DWPC 1975).

Detention and chlorination, nevertheless, is the approach that has been adopted by the MDC to the combined sewer overflow problems in the Boston Metropolitan Area. The Somerville Marginal Conduit and Overflow Pretreatment Facility, sans detention, was based upon this approach. The Somerville Facility was also partially funded with an EPA Stormwater Demonstration Grant. In 1978, in conjunction with a new Charles River Dam at Warren Avenue in Boston, construction will be completed on the MDC's Charles River Estuary Detention/Chlorination Facility. This facility, largely a replica of the Cottage Farm facility, is designed to collect combined sewer overflows from the Boston Marginal Conduit along the lower two miles of the Boston shore of the Basin, detain and chlorinate them and discharge them to Boston Inner Harbor. The separate urban stormwater problem has yet to be confronted in the Boston area.

1.3 EMMA Recommended Plan

The most recent water pollution control program proposed for the Boston Metropolitan Area is the Wastewater Engineering and Management Plan for Boston Harbor - Eastern Massachusetts Metropolitan Area (EMMA). The EMMA Study was authorized in July, 1972, by an agreement between the MDC, the Massachusetts Division of Water Pollution Control (DWPC) and Region I of the EPA. The study was conducted by the MDC through its principal engineering consultant, Metcalf and Eddy, Inc. By resolution of the United States Congress, also in 1972, and subsequent agreement between the Commonwealth of Massachusetts and the United States Army Corps of Engineers, the New England Division of the Corps of Engineers became a co-participant with the MDC in the EMMA Study. Other agencies participating with the MDC and the Corps as members of the EMMA Technical Subcommittee were:

- Region I EPA,
- the Massachusetts Department of Environmental Quality Engineering (DEQE),
- the Massachusetts Office of State Planning (OSP),
- the Massachusetts Division of Water Pollution Control (DWPC) and
- the Metropolitan Area Planning Council (MAPC).

A group of private citizens acted as a Citizens Advisory Committee to the EMMA Technical Subcommittee. The final report of the EMMA Study was completed in March, 1976, comprised of a brochure, summary report, main report and 23 Technical Data Volumes. The report was not released until June, after the public hearing and comment period for the MDC's NPDES permit were completed.

On August 12, 1976, Region I EPA and the Massachusetts DWPC jointly issued the new NPDES permit to the MDC. This permit adopted the EMMA Recommended Plan in its entirety, altering only the completion dates for the EMMA construction staging schedule to comply with the July 1, 1977 completion date required by PL 92-500. Accompanying the NPDES permit to the MDC was an Enforcement Compliance Schedule Letter (ECSL), which revised the permit compliance schedule back largely into conformance with the EMMA construction schedule. On September 13, 1976, EPA Region I approved the EMMA Plan as the Section 303(e) Water Quality Management Plan for Boston Harbor. The EMMA Recommended Plan thus became the focal point of this analysis of Water Quality Goals, Objectives, and Alternatives in the Boston Metropolitan Area.

The EMMA study recommended expansion, by the year 2000, of the present MSD service area from its present 43 communities to 51. The Deer Island sewage treatment plant would be expanded, in the EMMA Recommended Plan, to an average flow capacity of 400 million gallons per day (mgd) and upgraded to provide secondary treatment by the year 2000. The Nut Island sewage treatment plant would be expanded to 130 mgd and upgraded to secondary treatment. Sludge from both treatment plants would be incinerated at Deer Island. A 31 mgd advanced waste treatment (AWT) plant would be constructed in the middle reach of the Charles River and a similar 25 mgd AWT plant would be constructed on the upper Neponset River. The flow capacities of all these facilities were based on an average wastewater flow of 240 gallons per capita per day (gpcd). A number (between seven and 10, depending on which of the three alternatives presented in the EMMA study is put into effect) of detention/chlorination facilities, similar to the existing Cottage Farm facility on the Charles River, would be constructed on the lower Charles and Neponset Rivers, in the Dorchester Bay area of Boston Harbor and in

Boston Inner Harbor. The proposed Dorchester Bay detention/chlorination facilities are similar to the Old Harbor Plan, proposed some 10 years earlier by Camp, Dresser and McKee, Inc. as the initial construction phase of its deep rock tunnel plan, and its subsequent Tenean-Malibu Beach plan.

In addition to these major facilities, the EMMA plan includes a number of interceptor extensions, relief sewer constructions and pumping station repairs and replacements in conjunction with the recommended service area expansion. Construction of the EMMA Recommended Plan was estimated to cost $855 million at January, 1975 (ENR 2200) prices, with annual operating costs increasing from $8.3 million in 1974 to $29.5 million by the year 2000. The EMMA study examined storage, microstraining and chlorination as the control alternative for urban stormwater runoff in the Boston Metropolitan Area and estimated that stormwater control would cost an additional $465 million, with an annual operation and maintenance cost of $56 million. Urban stormwater control was thus not included in the EMMA Recommended Plan, "due to the preliminary nature of this study and because it is not expected that stormwater management will move rapidly in the direction of treatment." The EMMA study also identified a need for additional municipal facilities in the peripheral area (within the Boston Metropolitan Area but outside the expanded MSD) estimated at an additional $268 million, with annual operating and maintenance costs of $17 million. These estimates were exclusive of local collection sewers.

The EMMA study began with estimates of future population shifts from the inner city to the suburban metropolitan area, coupled with estimates of per capita water use, community sewerage and wastewater production. Plans for additional plumbing requirements (interceptors, pumping stations, etc.) were then developed for transport of the projected additional wastewater flows to various alternative discharge locations in the metropolitan Boston area.

Depending upon the wastewater type and discharge location, EMMA specified treatment processes to satisfy some of the letter of the Federal Water Quality Act (PL 92-500). Secondary biological treatment was specified for dry weather discharges to Boston Harbor. Advanced waste treatment (secondary plus some nutrient removal) was specified for dry weather discharges to tributary rivers. Some wet weather discharges were to be detained temporarily and chlorinated before continuing to be discharged to either the Harbor or tributary rivers. The single exception to these pre-selected treatment schemes was a large scale land disposal alternative examined late in the study and discarded as unworkable.

After the selection of the five seemingly arbitrary combinations of discharge locations, a preliminary, qualitative assessment was conducted of the impact of each combination on, among other things, water quality. In each case, water quality in Boston Harbor was projected to improve. No attempt, however, was made to assess whether projected improvements would be sufficient to satisfy water quality objectives; the EMMA study had no particular water quality objectives. Water quality in tributary rivers was projected to decline because of excess nutrients, viruses and toxic chlorine concentrations (EMMA vol. 13).

The procedural analysis used in this case study was precisely the reverse of the EMMA procedure: this study began with water quality goals and objectives (as does PL 92-500) and then progressed through the analysis to an assessment of the impact of these water quality goals upon wastewater management requirements and alternative water quality management strategies.

For the purposes of this analysis, the portion of the Boston Metropolitan Area directly affected by facilities in the EMMA Recommended Plan was subdivided into four main drainage basins: Boston Harbor and the Charles, Mystic and Neponset Rivers. The EMMA Recommended Plan and its projected water quality results were compared in each basin with alternative water quality management strategies that were proposed previously and that have been developed during the course of this case study. Because of the generally recognized significance, in the metropolitan Boston area, of water quality problems resulting from combined sewer overflows and urban stormwater runoff, and because of the inadequate response of the EMMA Plan to these problems, this analysis has emphasized alternative control strategies for these particular sources of pollution.

Of the various alternatives examined, intensive street cleaning and automated sewer flushing have appeared to be the most cost-effective approaches to the control of pollutants in combined sewer overflows. Intensive street cleaning in separate sewered areas was the most cost-effective approach to control of pollutants in urban stormwater runoff. Detailed discussions of these and alternative approaches can be found in Sections 7 and 8 and Appendices E, F and G in this report.

1.4 Boston Harbor

The general Boston Harbor area and the DWPC use classification of its waters are shown in Figure 1-1. The oceanside boundary of Boston Harbor is defined approximately by a line drawn from Point Allerton in Hull, northeast to the Boston Light House and finally to the southeastern point of Deer Island. This line encloses an area of approximately 50 square miles and includes 180 miles of shoreline and 30 islands with a total area of 1200 acres. There are two shipping channels, President Roads and Nantasket Roads, of about 40 feet mean low water depth; the Port of Boston in 1971 handled an estimated 24 million metric tons of cargo. Extensive areas of the Harbor have mean low water depths of less than 15 feet. The tidal interchange is about 73 billion gallons, twice daily, over a depth fluctuation of 9.5 feet. The maximum current in the main shipping channel is about two knots, occurring near Deer Island light about three hours after the beginning of flood tide.

A detailed description of the DWPC use classifications and associated water quality criteria is presented in Section 3 of this report. Generally, Class SA allows unrestricted shellfish harvesting, Class SB allows swimming and other body contact recreation and Class SC allows fishing. The classifications shown in Figure 1-1 were established in 1967 and, contrary to the requirements of Section 303(c) that applicable water quality standards be reviewed in public hearings at least once in each three year period beginning with the date of enactment of PL 92-500 these classifications have not been reviewed since.

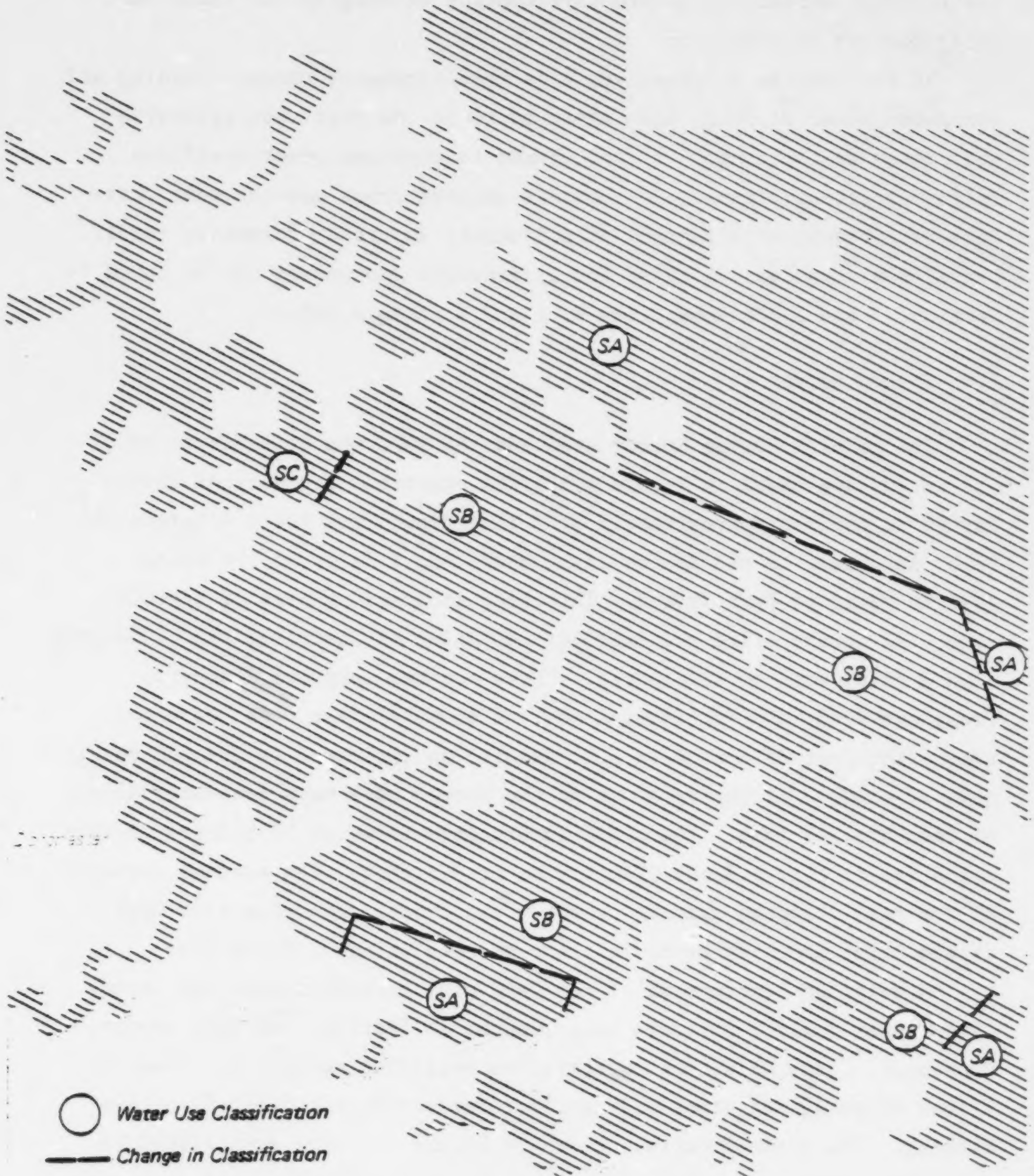
SA
SC
SB
SB
SA
Dorchester
SB
SA
SB
SA
Water Use Classification
Change in Classification

Figure 1-1 Boston Harbor

Inner Harbor

Boston Inner Harbor is presently used only for navigation, cooling water and waste disposal. With the recent and growing development of housing, condominiums, apartment complexes and marketplaces on the Boston Harbor waterfront, the Inner Harbor could potentially be a far greater recreational source than its degraded water quality allows it to be at present. Pollution of the Inner Harbor waters is overwhelmingly from combined sewer overflows and urban stormwater runoff, both directly into the Harbor and indirectly through the Charles and Mystic Rivers. Oil slicks float into the Harbor from the major tanker berths along Chelsea Creek and from the fuel and gas supply depots and tank farms at the mouth of the Mystic River in Charlestown and East Boston (Process Research 1976). Heavy metals concentrations in the water and sediments are highest here of any location in the harbor (N.E. Aquarium 1972, White 1972). The EMMA Recommended Plan includes $86 million for capital construction and $1.24 million in annual operating and maintenance (O&M) costs for the detention/chlorination of combined sewer overflows in the Inner Harbor. No stormwater pollution control provisions were recommended by EMMA. The EMMA Recommended Plan would not improve water quality in the Inner Harbor sufficiently to allow swimming (see Section 9 of this report). Alternatively, a sewer flushing system and an intensive urban street cleaning program that would result in swimming quality water in this area was estimated in this study (see Sections 8 and 9) to cost $12.3 million for capital equipment and $1.78 million in annual O&M costs.

Dorchester Bay

Dorchester Bay in Boston Harbor is the most intensively used water recreation area in metropolitan Boston. About 270 acres of public beaches are maintained by the MDC around the perimeter of Dorchester Bay. Present water quality at the northern area beaches, Pleasure Bay, L-Street and Carson Beach, is generally acceptable for swimming. Water quality at the southern area beaches, Malibu and Tenean, is marginal, particularly after rainfall events, although the two beaches have not been closed to swimming during the past several years. Water quality in

Dorchester Bay is dominated by combined sewer overflows, primarily into the southern area and the mouth of the Neponset River. Dry weather sewage also overflows continuously into the mouth of the Neponset from the Port Norfolk area of Dorchester, because the sewer connection from this area to the Dorchester Interceptor has for many years been blocked with debris (Process Research, Inc. 1975). The EMMA Recommended Plan includes $100 million for construction of combined sewer overflow detention/chlorination facilities in Dorchester Bay and at the mouth of the Neponset River. Annual O&M for these facilities was estimated at $1.44 million. These facilities would result in swimming quality water throughout Dorchester Bay. A sewer flushing system in this area, which would provide equivalent or higher quality water, would cost $9.2 million for capital equipment and $0.66 for annual O&M.

Quincy Bay

Quincy Bay is the second most highly used water recreation area in Boston Harbor. The MDC maintains 19 acres of public beach along the 2.5 mile shoreline at Wollaston in Quincy. A major restricted harvesting shellfish bed is also located at the easterly end of Wollaston Beach. Water quality in Quincy Bay routinely satisfies the Massachusetts swimming quality criteria but not the unrestricted shellfishing criteria. The primary direct source of pollution in this area is urban stormwater runoff from the City of Quincy. Other indirect sources probably influence water quality in Quincy Bay more than the direct stormwater runoff. Untreated sewage from the Moon Island overflow facility can flow into Quincy Bay if discharged on an incoming tide, and combined sewer overflows from the Inner Harbor and Dorchester Bay are dispersed to some extent as far south as Quincy Bay. The outfall from the Nut Island primary treatment plant is located at the seaward edge of Quincy Bay and is a major influence on water quality in the Bay. The EMMA Recommended Plan would expand the Nut Island plant to 130 mgd and upgrade it to secondary treatment. With adequate control of Inner Harbor combined sewer overflows, this would appear to satisfy even the unrestricted shellfishing criteria in Quincy Bay. The estimated Nut Island system costs associated with the EMMA recommended expansion and upgrading were $147.7 million for construction and $4.1 million annually for O&M.

Outer Harbor

The largest single point source discharge in the Boston Metropolitan Area, the Deer Island primary treatment plant outfall, is located at the seaward edge of the Outer Harbor. Sludge from both Deer and Nut Islands is also discharged in this area on outgoing tides. Principal uses of the Outer Harbor are navigation, recreational boating, sport fishing and swimming and picnicking at the Harbor Islands. The present Harbor Island Development Program is expected to expand the recreational use of the islands to about two million person days per year, with projected economic benefits of $6 million yearly (MAPC 1972). The present water quality in the Outer Harbor consistently fails to satisfy the bacterial criterion for Massachusetts Class SB waters, although this is as much due to the combined sewer overflows in the Inner Harbor as to the chlorinated treatment plant discharges. The EMMA Recommended Plan would eliminate the present sewage sludge discharges to the Harbor and expand and upgrade the Deer Island facility to a 400 mgd secondary treatment plant. Costs associated with the expanded Deer Island system were estimated to be $302.5 million for construction and $12.35 million for annual O&M.

Wastewater Projections and their Implications

The EMMA-recommended treatment facilities were sized for quite generous dry weather wastewater flow projections: 274 gpcd for the Deer Island service area and 193 gpcd for the Nut Island service area by the year 2000. One hundred and eighty-five gpcd were assumed for the estimated populations tributary to the satellite plants on the Charles and Neponset Rivers. The first difficulty with the EMMA-increased wastewater flow projections is that they are inconsistent with EPA-recommended policies of flow reduction, infiltration/inflow correction, water conservation, etc. If wastewater flows are projected more nearly in accord with recently proposed EPA Cost Effectiveness Analysis Guidelines, or from actual Boston area flow measurements, then much smaller treatment facilities would be required in Boston Harbor. A 136 mgd secondary treatment plant, including an expanded primary stage, at Nut Island could eliminate the need for the EMMA-recommended satellite AWT plants on the Charles and Neponset Rivers. The cost of such a system, including the necessary extension sewers to new service areas and interceptors from satellite locations, was estimated at $272.6 million for construction and $5.1 million for annual O&M. The year 2000 Deer Island treatment plant capacity would only need to be 312 mgd, including an excess capacity of 100 mgd for wet weather flows. A 312 mgd secondary treatment plant at Deer Island, including the expanded primary stage and other improvements suggested by Kennedy Engineers, was estimated to cost $314.5 million for construction and $20.8 million for annual O&M. (All sludge management was assumed to take place at Deer Island.) I/I correction costs associated with these reduced flows were estimated (by Kennedy Engineers) at $192 million.

A second difficulty with the EMMA dry weather flow projections is that they would occupy virtually all the available combined sewer interceptor capacities in the Boston area, leaving the EMMA-recommended wet weather detention/chlorination facilities no way for emptying. They would accomplish nothing more than chlorination. Water quality projections throughout Boston Harbor would thus depend critically on the assumption that simply chlorinating raw sewage is an adequate pollution control policy. There are reasons to suspect serious problems with this practice. If the practice does destroy coliform bacteria, then it would be cosmetically masking the only indicator used routinely to detect the presence of pathogenic organisms, because it would not much affect virus populations. There is reasonable doubt about its effectiveness even with bacteria, if data from the Cottage Farm facility are any indication. Since either the chlorinators or the sampling equipment seemed nearly always to be inoperable (MDC 1976), the bacterial quality data for the three years of its recorded operation seem largely to have been estimated. (Historical experience indicates that adequate disinfection of raw sewage would need about 10 times the chlorine used at Cottage Farm and as much as two hours detention.) Certainly no other pollutants would be removed by these facilities, and some would be added. Carcinogenic chlorinated organic compounds would be produced, and toxic concentrations of chlorine itself are required by the present NPDES permit conditions (minimum of 1.0 mg/l chlorine residual). If the effectiveness assumed by the EMMA Study for chlorination of combined sewer overflows was disbelieved, water quality criteria in Boston Harbor would not be satisfied by the EMMA Recommended Plan at a single location. Much the same arguments about chlorination efficacy might well be made (though not quite so strongly) about primary effluents. If EPA were to discount this practice, secondary treatment would be required at Deer and Nut Islands on water quality considerations alone, regardless of the stipulation of section 301(b)(1)(B).

1.5 Charles River

The Charles River begins its course at Echo Lake,* which is situated approximately 350 feet above sea level in the gently rolling hills of Hopkinton near the Rhode Island-Massachusetts boundary. Figure 1-2 shows its meandering 80-mile course that proceeds in a northeasterly direction before its ultimate dischage to Boston Harbor. At this final point in its course, the river is partitioned from the Harbor by the Charles River Dam, a 65-year-old sluice gate dam that is presently being replaced by the Army Corps of Engineers with a more efficient structure that will retard saltwater intrusion and control flooding in the Lower Charles River. The Charles River has one of the flattest gradients of any stream in Massachusetts, with a total drop of about 350 feet in 78 miles. Figure 1-3 shows the profile of the river. For most of its length the river is quite shallow, often running only about three feet in depth, and narrow, normally 50 to 100 feet wide. Its size increases below the Watertown Dam, reaching a maximum depth of 25 feet and width of 2000 feet.

Within the 307 square mile drainage area are 33 lakes and ponds having a total surface area of 2530 acres. In addition, there are numerous backwater ponds created by the 21 dams existing on the river. There are 13 significant tributaries and two diversions branching the Charles along its length. Mother Brook diverts up to one-third of the

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*During low flow periods the source of the Charles River is the outfall from the Milford sewage treatment plant.

Franklin
Mine Bk.
Lake Pearl
Wrentham

Figure 1-2 Charles River Basin

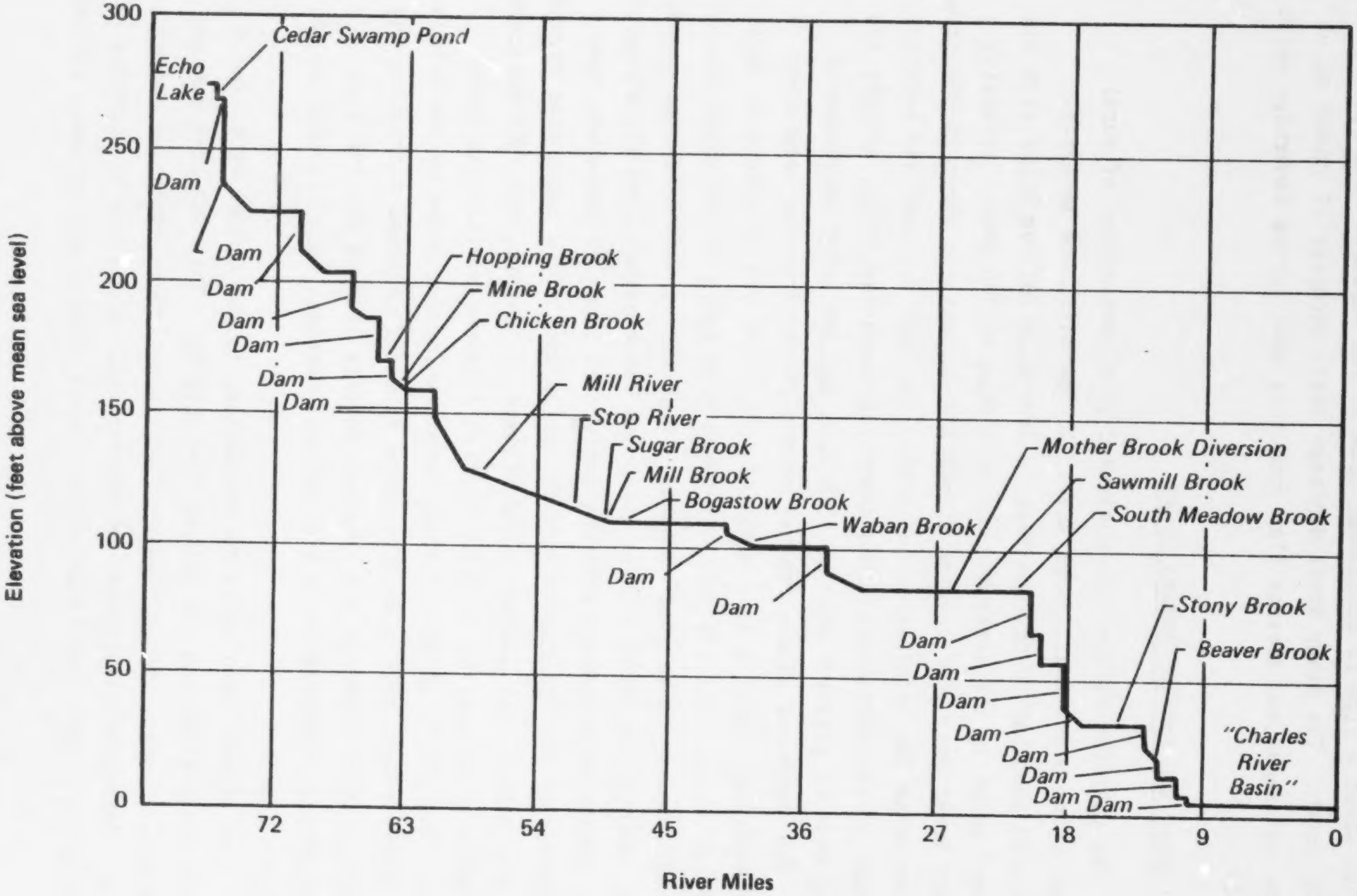

Figure 1-3 Charles River Profile

Charles River's flow to supplement flow in the Neponset River that lies to the south. The Stony Brook drainage basin occupies 23 square miles of the watershed and diverts flow from this area to the Cambridge water supply.

Upper and Middle Charles River

The upstream half of the watershed is a combination of rural areas, where a few small farms are still operated, and moderately populated suburban towns. Terrain is generally rolling hills with the highest point in the watershed divide rising to 560 feet. Extensive swampy areas and brush-covered floodplain account for about 20,000 acres or one-tenth the total watershed area. The soil is sandy and pervious. Because of its attractive flood dampening characteristics, efforts are being made to preserve much of this area against urban encroachment.

The upper and middle reaches of the river, from the headwaters to Watertown Dam, provide many areas of open space and recreational facilities. Although there is little publicly-owned open space in the upper reaches of the Charles, there still remains a significant amount of undeveloped land, much of it swamp. There are areas where naturalized rhododendrons have become established, offering attractive views to those who take advantage of the informal system of trails and bridle paths that abound in this region. At Charles River Village in Needham, the YMCA operates a recreational boating facility with an adjacent public boat launch area. The nearby 29-acre Charles River Peninsula, owned by the Trustees of Reservations, offers an attractive site for informal picnicking and walking. Also owned by the Trustees in this area is the 109-acre Rhododendron Reservation in the Medfield Marshes, which is kept in its natural state.

The largest open space on the Charles is the Cutler Park, Saw Mill Brook Reservation and Cow Island Pond complex. This 700-acre complex combines a large, undisturbed bird sanctuary and an extensive recreational area. Intensive development of recreational facilities is confined to a relatively small area that houses tennis courts, playgrounds, athletic fields, picnic areas, a boat launch, an ice skating rink and an olympic-sized swimming pool. Hiking paths, which provide natural field laboratories for local schools, are maintained in the bird sanctuary. A new canoe launch facility was recently opened to provide access to the many streams within the sanctuary.

Most of the 8-mile shoreline from Hemlock Gorge to Riverside has been set aside as a "green belt" with many foot and bicycle paths. At one time Riverside was an extensive recreation area. By 1898 its facilities consisted of an outdoor swimming pool, restaurant, six tennis courts, racks for 150 canoes, athletic fields and a quarter-mile cinder running track. Heavy use was experienced until 1950, when declining revenues fell below expenses, and maintenance funds were not available. In 1959 the buildings were destroyed by fire, the site was filled in and the facilities were replaced by a golf course. The Metropolitan Area Planning Council has proposed that facilities for tennis, picnicking, canoeing and team sports be redeveloped here.

Prior to the mid-1950's, the recreation center at Norumbega Park was a popular day excursion area. With its amusement area, landscaped park, and canoe and paddle boat facilities, it offered a diversity of activities. Today most of the park is occupied by a large motor hotel. The only public area remaining is a small duck feeding area on the west bank. If additional land were acquired and the water quality was improved, the lake-like impoundment could again be used for swimming and fishing. It is used today for canoeing and picnicking.

Water quality is the principal limitation for recreation on the upper and middle Charles, especially during the summer months. At one time, water quality met swimming quality standards. Since 1959, however, all beaches have been closed due to high coliform bacteria levels. The water is generally aesthetically unpleasant. It is usually brown and turbid, and from summer through fall algae and duckweed are found floating on the surface. Some of the algal species, usually blue-green, cause the water to be malodorous, as do the sewage treatment plant discharges. In many areas, especially those that are industrialized or heavily populated, there is much man-made debris in the water and along the shoreline. In some impounded areas rooted aquatic plant growth makes passage by boat or canoe difficult and sometimes impossible. There are numerous dumps and landfills on the banks of the river, the largest being the landfill operated by the City of Boston in West Roxbury.

The EMMA Recommended Plan does not include any facilities on the upper Charles River, but a number of AWT plants are either proposed or under construction in this area. There are continuing debates among state and federal water quality modelers about whether the dissolved oxygen criteria in the upper and middle reaches of the river will be satisfied after construction of these treatment plants. The argument is moot, since the phosphorus discharges from these plants will continue to be more than enough to stimulate sufficiently offensive algal blooms and aquatic plant growth as to preclude swimming quality water. The flow in the Charles River is simply too small to accommodate any wastewater effluent of any magnitude. It appears possible to achieve swimming quality water in the upper and middle Charles, but only if all sewage flows were diverted to land application. Additional control of nutrients from urban runoff would require that intensive street cleaning practices be adopted by all municipalities along the river. The necessary street cleaning operations along the upper Charles (above the South Natick Dam) were estimated in this study to cost $5.3 million for capital equipment and $5.3 million annually for O&M (see Section 8 of this report). No cost differential was assumed between land treatment and the proposed upstream AWT plants, although the similar comparisons for the EMMA recommended AWT satellites and land treatment showed the latter to be less expensive.

The 31 mgd satellite AWT plant recommended by the EMMA Plan on the middle reach of the Charles would degrade water quality from its location on downstream, due to the unacceptable phosphorus concentrations in AWT effluents. This facility, and associated interceptors, was estimated to cost $78.9 million for construction and $2.84 million annually for O&M. If it were necessary to locate a treatment plant on the middle Charles, 31 mgd secondary treatment plant, with an effluent force main to President Roads in Boston Harbor, would cost only $58.4 million for construction and $1.1 million for annual O&M. A comparable land treatment facility, with interceptor extensions, that would not degrade water quality was estimated at $71.6 million for construction and $1.15 million for annual O&M. Even with land treatment instead of AWT in the middle Charles, intensive street cleaning would be required to satisfy the swimming quality criteria in this area. The costs of the necessary street cleaning operations along the middle Charles were estimated in this study to be $6.25 million for capital equipment and $6.25 million annually for O&M. These would be necessary in addition to the street cleaning operations along the upper Charles River and the conversion of all upstream AWT plants to land treatment. It should be noted that the need for a mid-Charles treatment facility of any sort arose primarily because of the EMMA study wastewater flow assumptions. Flow augmentation or elimination of extra-basin water transport may still be adequate justifications for locating a treatment plant on the Charles, and correspondingly reducing the size of the Nut Island treatment plant, but water quality considerations dictate that any treatment plant anywhere on the Charles River be a land treatment facility.

Charles River Basin

The Charles River Basin begins at the Watertown Dam and stretches through the highly urbanized center of the Boston metropolitan area. The 8-mile-long Basin consists entirely of backwater from the Charles River Dam. It is a stratified impoundment, fed by upstream flows over the Watertown Dam and stormwater and combined sewer overflows from Boston and Cambridge. It is bounded on both sides by high-speed highways. Between these roads and along the riverbanks, runs a narrow green park area that is used for limited recreational purposes. The Charles River Basin was the backbone of the original inland system of open space for metropolitan Boston. The Basin and its associated parkland separated the dense development of downtown Boston and Cambridge. It created scenic areas that offered exceptional views of the urban skylines and provided recreational space for city dwellers. "The view from Cambridge across the Charles River Basin, with sailboats in the foreground and Beacon Hill and the State House dome in the background, is one of the most famous in the metropolitan area and is a world-wide symbol of the city of Boston" (MAPC 1969).

Although originally unattractive, the Basin was developed into a major recreational area by the early twentieth century. Upon completion of the Charles River Dam, which created the present Basin, the open space bounding the river in Boston consisted of a narrow concrete walk just in back of the houses on Beacon Hill. Over the past 60 years, using landfill, the present continuous "green corridor" between the Charles River Dam and Watertown Dam was created. This parkland, under the auspices of the Metropolitan District Commission, provides a major recreational potential for core city dwellers. The Back Bay Fens, which is contiguous with the "green corridor," provides an additional 113 acres of open space along the Muddy River. It provides play areas, athletic fields and a large area used by local residents for garden plots.

Sailing is a major recreational activity on the Charles, and many facilities are provided for this sport. Community Boating, Inc. maintains a fleet of 46 sailboats for rental (Metropolitan Planning Council 1969). Approximately 1,800 teenagers buy yearly memberships, and more than 2,000 adults pay for sailing lessons and use of the boats. The Massachusetts Institute of Technology maintains 49 sailboats for use by the MIT Nautical Association, which has a membership of over 1,000. In addition, Harvard University has 28 sailboats, Boston University 16, and Boston State College 12, which are used by their respective nautical associations. Other forms of boating are also popular. Crew and sculling range from individual to the large 8-man shells used by college crew teams. Five major colleges maintain facilities for these sports at their boathouses. Six yacht clubs provide the major areas for berthing and maintenance for the 1,200 privately owned pleasure craft on the river. Public launching areas are found at Magazine Beach in Cambridge and on Soldiers Field Road in Boston.

Swimming and sport fishing, although once popular pastimes, have been lost over the past two decades due to poor water quality. Six beaches at one time provided swimming areas, but all have been closed since 1959. Sport fishing has been almost nonexistent since the loss of the anadromous fish runs. The new Charles River Dam at Warren Avenue, now under construction with facilities to accommodate anadromous fish runs, is expected to restore shad fishing if water quality can be improved. In addition to increased sport fishing, the dam will reduce flooding dangers (in an area with property valued at $200 million), improve boat traffic by reducing locking delays and reduce saltwater intrusion.

The Charles River Basin occupies a position unique in American history. The nation's first printing press was floated up the Charles on a sailboat and installed at the riverside, where the nation's first book was published. On the opposite bank, the first American newspaper was printed. The first English-speaking university in the New World was founded at the swampy edge of the Charles, where it exists today. In 1775, George Washington accepted command of the Continental Army at a Cambridge parade ground (McVicar 1972). The Charles has seen the beginnings of technologies that have forever revolutionized the way of life in America. The first remote telephone call took place across the Charles River, from Alexander Graham Bell in Boston to Thomas Watson in a warehouse in Cambridgeport. The first version of the electronic computer was invented at one of the great universities along the Charles, and landings of humans on the face of the moon and explorations of the reaches of our solar system have been designed and controlled by scientists on the banks of the Charles River. It befits the dignity of this small but historic river that it bears so stoically the degradation its citizenry suffers upon it.

Water quality in the Charles Basin can best be described as dismal. Water contact sports are prohibited by high bacteria concentrations discharged into the Basin by combined sewer overflows and the Muddy River. The water is brown and turbid, and in late spring, summer, and fall massive algae blooms can cause mats of floating algae over much of the Basin surface. These mats give off highly offensive odors, making the whole area aesthetically unpleasing. Throughout the year oil and debris can be found on the surface, in some cases making motor boating hazardous. The shoreline is covered with an oil slick and is littered with trash.

The EMMA Recommended Plan calls for three additional detention/chlorination facilities in the Charles River Basin, at an estimated construction cost of $84 million and annual O&M costs of $1.2 million.

These facilities, combined with an EPA-financed MDC destratification project in the Basin, will have a result heretofore not believed possible. They will result in even poorer quality water in the Basin than there is at present. Destratification will remove the bacteriocidal and algal-growth-limiting effects of the presently high salt concentrations. Mixing of polluted stratified bottom layer with surface waters in the Basin will redistribute these pollutants throughout the water column, releasing large concentrations of hydrogen sulfide to the surrounding atmosphere in the process. The detention/chlorination facilities will not adequately reduce loadings of bacteria, phosphorus or organics. The facility proposed for the Back Bay Fens area, for example, seems particularly undersized even for the EMMA study design criteria. Alternatively, a combined sewer flushing system and urban street cleaning program designed to achieve swimming/fishing quality water in the Charles Basin was estimated at $18.4 million for capital costs and $3.7 million for annual O&M. These costs in the Basin area would be in addition to the street cleaning operations ($6.25 million for capital costs and $6.25 million annual O&M) along the middle Charles that would be necessary to reduce upstream phosphorus flows into the Basin to acceptable levels for algal growth limitation.

1.6 Mystic-Aberjona River System

The Mystic-Aberjona River System, shown in Figures 1-4 and 1-5, is about 18 miles long, the Aberjona River beginning in Reading and flowing generally due south into the Upper Mystic Lake. Pollution of the Aberjona is primarily from nonpoint sources and urban stormwater runoff, although some raw sewage overflows have been reported to tributary streams. Water quality is uniformly poor throughout the Aberjona, with extremely low dissolved oxygen and high concentrations of biochemical oxygen demand (BOD) and coliform bacteria and toxic concentrations of nitrogen compounds. Many of these water quality problems can be traced to the lingering aftereffects of a now-discontinued discharge of an extremely acidic and nitrogenous industrial waste to a swampy area near the source of the river. Drainage from this swampland will probably continue to degrade the Aberjona for many years, unless diverted, treated or otherwise corrected. The Woburn Sanitary Landfill, an

Figure 1-4 Mystic River Basin

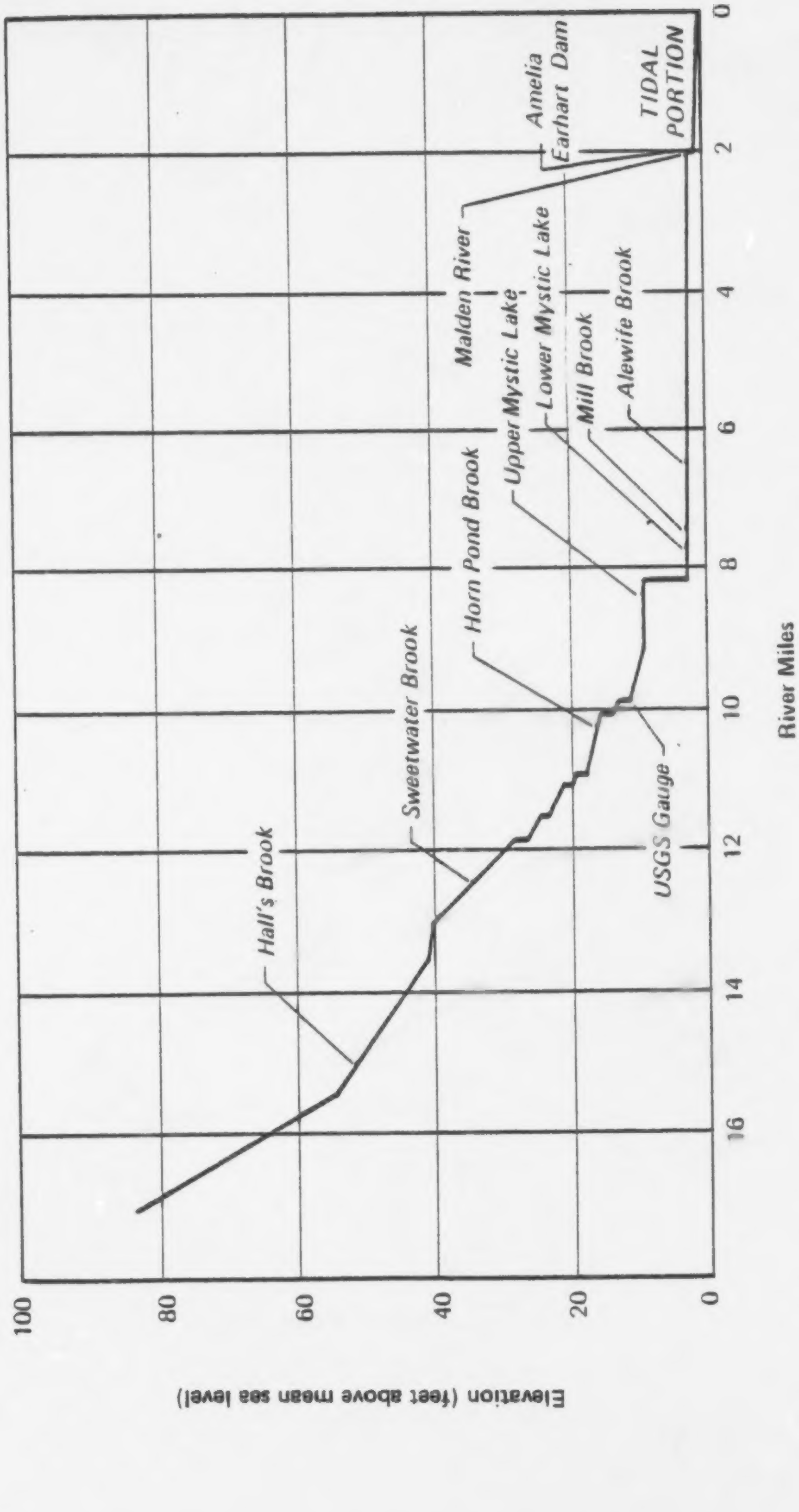

Figure 1-5 Aberjona - Mystic River System Profile

industrial park and an auto wrecking yard are also located in this area. Flow in the Aberjona River has been observed to decrease as it flows downstream because of extensive industrial and municipal reliance upon groundwater supplies in the area and the subsequent export of this water out of the basin through the regional MDC sewerage system.

The Aberjona River flows into the Upper Mystic Lake and is believed to be the source of toxic concentrations of ammonia-nitrogen, as well as zinc, in this lake (DWPC 1974). Because of this problem, and low oxygen concentrations in much of the lake, the Division of Fisheries and Game no longer stocks the Upper Mystic Lake with trout.

The Lower Mystic Lake is stratified by a large salt water volume trapped at the bottom of the lake by the MDC's Amelia Earhart Dam downstream on the Mystic River. This salt water layer, much like that in the Charles River Basin, has become anaerobic because of the decaying algae and other organic materials settling into the bottom waters. It contains massive concentrations of phosphorus, nitrogen and hydrogen sulfide. Although the surface water quality in the Lower Mystic Lake is improved from that in the Upper Mystic Lake, nutrient concentrations are still high enough to result in offensive algal blooms in the summer months. Because of the population proximities and extensive publicly owned park and reservation lands maintained along the shores of the Mystic Lakes and lower reach of the Aberjona River, the recreational use potential of these waters is high, second only to that of the Charles River Basin in the Boston Metropolitan Area. That this potential is inadequately realized is due, as with the Charles, to unacceptable water quality.

The Mystic River, from the outlet of the Lower Mystic Lake downstream some five and one-half miles to the Amelia Earhart Dam at the confluence with Boston Inner Harbor, is polluted by urban stormwater runoff and combined sewer overflows. High concentrations of nitrogen and phosphorus from these sources and from the Lower Mystic Lake result in nuisance growths of algae and aquatic plants the length of the River. The EMMA Recommended Plan proposed no control facilities on the Mystic River, but the existing Somerville Overflow Pretreatment (screening and chlorination) Facility was offered as an adequate control measure for combined sewer overflows in spite of the conclusion in a preliminary draft report on its performance evaluation (C. E. Maguire, Inc. 1976).

> The foremost conclusion which can be drawn from the Somerville Pretreatment Facility is that this inexpensive approach to combined sewage treatment is, at this time, inappropriate.

A combined sewer flushing system and urban street cleaning program in the drainage area of the Mystic River designed to upgrade the Mystic to swimming/fishing quality water was estimated in this analysis to cost $3.2 million for capital construction and equipment and $1.3 million for annual O&M.

1.7 Neponset River

The 123 square mile drainage area of the Neponset River is shown in Figure 1-6, with the existing DWPC use classes for the river. The profile of this river, with existing dams and impoundments is shown in Figure 1-7. The use of the Neponset as a conveyor of industrial wastes dates to the first white settlements in the Boston area. The possibilities of the river's lowermost falls for water-powered industrial development were noted during the early settling of the Massachusetts Bay Colony. The first bushel of corn that was ground by water power in New England was presumably ground in the mill constructed at this location by Israel Stoughton in 1634. Other mills were soon constructed in this area along both sides of the river, producing chocolate, gunpowder, paper, artificial legs, base violins, pianos, drugs, medicines and dyestuffs. The original settlements upstream on the Neponset were largely agricultural communities, but many factories were subsequently constructed in the Walpole area.

As many as 11 water power dams existed by the mid-nineteenth century between the source of the Neponset and the Hollingsworth and Vose Pond. Grist mills and factories for the manufacture of cloth, nails, woolen goods, boots and shoes, yarn, cotton thread, machinery stoves, fire frames, snuff, forged iron, mattresses, cotton batting, lamp wicks, felt, hats, paper goods and roofing supplies have used the water power of the Neponset River in the Walpole area. Paul Revere

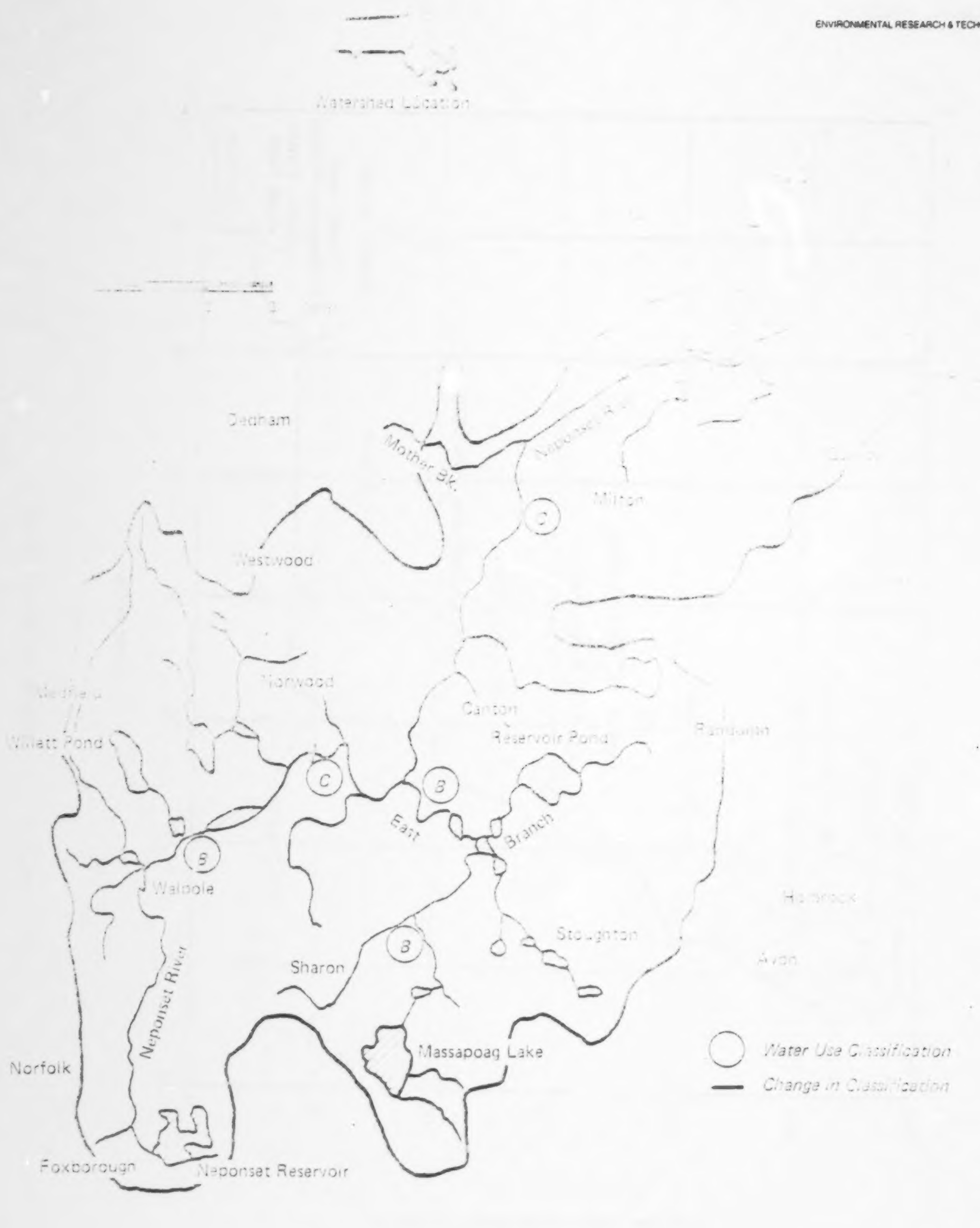
Watershed Location
Dedham
Mother Bk.
Neponset River
Quincy
Milton
C
Westwood
Medfield
Norwood
Canton
Reservoir Pond
Randolph
Willett Pond
C
B
East Branch
B
Walpole
Holbrook
Stoughton
B
Avon
Sharon
Neponset River
Massapoag Lake
Norfolk
Foxborough
Neponset Reservoir
Water Use Classification
Change in Classification

Figure 1-6 Neponset River Basin

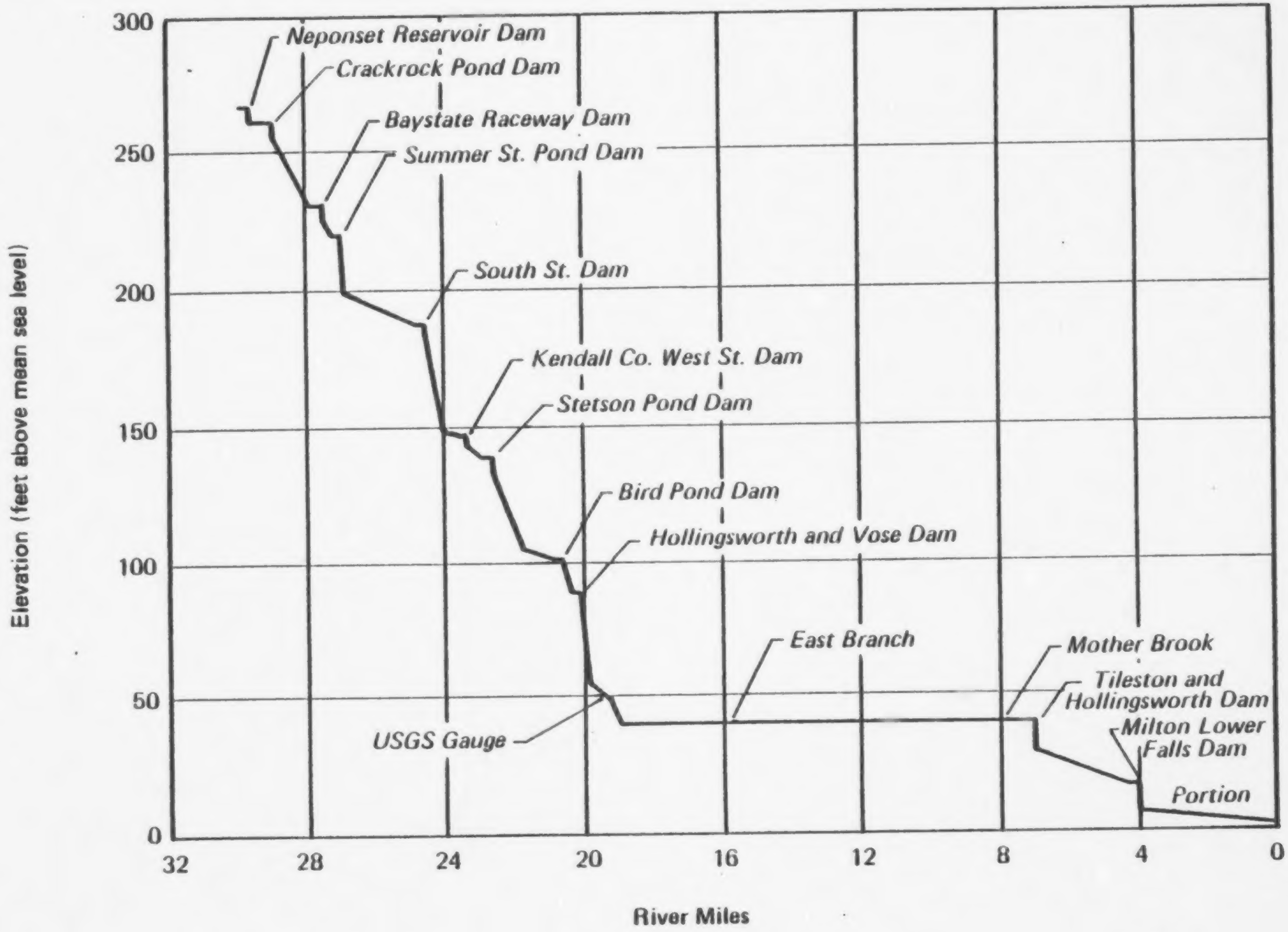

Figure 1-7 Neponset River Profile

established a powder factory on the East Branch of the Neponset, which operated during the Revolution and the War of 1812. Revere also constructed the first copper rolling mill in the United States in 1808 along the East Branch. This mill provided the copper for the Massachusetts State House Dome and made the boilers for Fulton's first steamboat. Other manufacturing operations on the East Branch produced iron implements, steel, cannons, bells, cotton, silk, wool and yarn. The largest stove polish manufacturing company in the world was established here in 1858. Today, a series of industrial point source discharges begins at the headwaters of the Neponset River at Neponset Reservoir in Foxboro and continues down to its confluence with the East Branch. Dissolved oxygen is low in the summer months throughout this upper section of the river.

After the East Branch joins the Neponset, there are no further significant point source discharges down to the Mother Brook diversion. Most of this section of the river is the Fowl Meadow Marsh, between the Blue Hills and Neponset River Reservations. The EMMA Recommended Plan proposes the location of a 25 mgd AWT plant in this area, at an estimated construction cost of $56 million and annual O&M costs of $2.4 million. This facility would further degrade water quality in the Neponset River because the AWT effluent phosphorus concentration would be ten times higher than the marginal levels presently found in the river in this section. Alternatively, a secondary satellite treatment plant with force main transmission of secondary effluent to President Roads in Boston Harbor would cost only $38.9 million for construction and $0.95 million for annual O&M. Diversion of all point source discharges on the Neponset to land treatment facilities, coupled with intensive urban street cleaning, would satisfy swimming water quality in the river. A 25 mgd satellite land treatment facility was estimated to cost $50.4 million for construction and $0.9 million for annual O&M. Urban street cleaning in tributary areas along the Neponset was estimated to cost $3.5 million for capital equipment and $3.5 million for annual O&M. The further upstream any land treatment facility was located, the greater would be the water quality benefits.

The lower Neponset River, beginning at the Mother Brook diversion, is polluted primarily by urban stormwater runoff and Charles River water from Mother Brook. Mother Brook is a man-made canal between the Charles and Neponset Rivers, constructed in 1640 to provide water power for a grist-mill built at the same time. One-third of the flow in the Charles is presently diverted through Mother Brook for low flow augmentation of the Neponset and flood relief for the Charles. Even a casual inspection of water quality data from the two rivers provides fairly convincing evidence that this diversion is not profoundly beneficial to the Neponset. Water quality in the Neponset upstream of the Mother Brook confluence is routinely superior to that in the Charles upstream from its diversion. Concentrations of BOD, nitrogen, phosphorus, suspended solids, algae and coliform bacteria in the Neponset River all increase sharply at the Mother Brook confluence. Elimination of the diversion, except for flood relief, would improve water quality in the Neponset.

1.8 Summary of Water Quality Benefits and Costs

The management, or investment, strategy alternatives examined in this study were grouped into three categories. These alternatives are described in detail in Sections 8 and 9 of this report. All alternatives assumed the discontinuance of the present sludge discharges to Boston Harbor. Category I was concerned with making the maximum use of the present MSD system by repairing and upgrading existing primary treatment facilities, rehabilitating existing sewers and correcting infiltration/inflow problems. This category thus considered lower wastewater flow projections than did Categories II and III. Category I also emphasized rigorous control of pollution from combined sewer overflows and urban stormwater runoff.

The alternatives in this category were arranged in three investment sequences. The first sequence considered upgrading of the present MSD system only (IA, IB); the second added the expansion of the system as recommended by the EMMA plan (IC). Both included automated sewer flushing and urban street cleaning alternatives in various locations and of sufficient intensities to achieve swimming/fishing quality waters

(ID.2&4a-d). Both of these first two sequences were, therefore, designed to be representative of water quality management plans. The third investment sequence, for comparison purposes, replaced the sewer flushing and street cleaning alternatives in sequence 2 with the EMMA-recommended detention/chlorination facilities (ID.5).

The Category II alternatives were the EMMA plan as recommended (IIA) and with some modifications of the primary stages of the Deer and Nut Island treatment plants (IIB). Wastewater flow projections for this category were those in the EMMA Recommended Plan. Category III was also based on the EMMA flow projections and consisted of a series of alternatives to the EMMA-recommended treatment facilities. All Category III alternatives included the EMMA-recommended detention/chlorination facilities for combined sewer overflows. All Category II and III alternatives were considered to be wastewater management plans, rather than water quality management plans, since they were not designed on the basis of quantitative water quality requirements.

The present worth of each alternative was computed according to EPA Cost Effectiveness Analysis Guidelines (40 CFR 35). The water quality impact of each alternative and combination of alternatives was assessed for each of the 19 water quality sections examined in this analysis. Tabulations were made for those sections in which the swimming/fishing quality criteria would be satisfied. Estimates of the potential annual benefits of acceptable quality water in each section were developed from relative population proximities and recent willingness-to-pay surveys in the Boston area (see Section 9 and Appendix I).

Present worths for the resulting benefit time streams were computed, and the various alternative management, or investment, strategies were compared on the basis of their respective benefit/cost ratios. These comparisons are summarized in Table 1-1. In this table, water quality sections C1-C8 are those of the Charles River; M4 is that of the Mystic River; N1-N3 are those of the Neponset River and BH1-BH4 are those of Boston Harbor. Descriptions of each section can be found in Section 4 of this report.

TABLE 1-1

WATER QUALITY BENEFIT/COST ANALYSIS OF ALTERNATIVE INVESTMENT STRATEGIES

				Conditions with Effluent Chlorination		
		Alternatives	Present Worth Costs ($ millions)	Acceptable Water Quality Sections	Present Worth Benefits ($ millions)	Benefit/Cost Ratio
Category I:		Sequence 1, A, B, D.2&4a-d	457.0	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.97
		with E.1, secondary treatment	607.1	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.73
I:		Sequence 2, A, B, C, D.2&4a-d	487.2	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.91
		with E.2, secondary treatment	641.4	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.69
I:		Sequence 3, A, B, C, D.5 (EMMA)	454.3	BH1-BH4	107.2	0.24
		with E.2, secondary treatment	608.5	BH1-BH4	107.2	0.18
Category II:	A.	EMMA Recommended Plan	603.0	BH2-BH4	84.8	0.14
	B.	EMMA with STP additions	653.3	BH2-BH4	84.8	0.13
Category III:	A.	No satellite plants	582.4	BH2-BH4	84.8	0.15
	B.	Two secondary satellites, effl. to B.H.	581.2	BH2-BH4	84.8	0.15
	C.	Two secondary satellites, effl. to rivers	563.0	BH2-BH4	84.8	0.15
	D.1	Two land treatment satellites	576.1	BH2-BH4	84.8	0.15
	.2	with 1D.4b-d street cleaning	670.3	C1-C6, N2, N3, BH2-BH4	262.0	0.39
	.3	with land at upstream locations	670.3	C1-C6, N1-N3, BH2-BH4	283.8	0.42
	E.	One secondary satellite, effl. to B.H.	575.8	BH2-BH4	84.8	0.15
	F.	One secondary satellite, effl. to Nep.	564.1	BH2-BH4	84.8	0.15
	G.1	One land treatment satellite on Nep.	582.7			
	.2	with land at upstream location	582.7	N1-N3, BH2-BH4	163.9	0.28
	H.	One AWT satellite on Neponset River	597.6	BH2-BH4	84.8	0.14
	J.	Primary treatment, effl. to ocean	475.7	BH2-BH4	84.8	0.18
	K.	Primary treatment, effl. to Harbor	390.9	BH2-BH4	84.8	0.22

Generally, projected water quality benefits are greatest and benefit/cost ratios are highest for the Category I water quality management plans, because they were designed on the basis of water quality requirements. Benefits and benefit/cost ratios are lowest for the EMMA Recommended Plan, because this plan was not based on water quality requirements but on those of wastewater management.

Because of the very heavy reliance of Boston area water quality projections on not well documented assumptions as to the efficacy of chlorinating combined sewer overflows and primary sewage effluents, a second examination of alternatives was made. This examination considered all the same alternatives but without chlorination. The results of the comparisons of alternatives on this basis are summarized in Table 1-2, where the differences among alternatives become much more clearly defined. If the Boston area assumptions about the effectiveness of chlorinating very poorly treated sewage are in error, or if the chlorination practice is discontinued because of toxicity or other hazards, then the EMMA plan will result in no water quality benefits anywhere in the Boston area. Conversely, those strategy alternatives that do not rely so heavily on chlorination (Category I) are not so sensitive to assumptions about its efficacy. The differences that do appear between Tables 1-1 and 1-2 in the present worths of benefits in Category I are due to the timing of water quality improvements in Boston Harbor. In Table 1-1, Sections BH3 and BH4 would become acceptable after the present sludge discharges to the Harbor are discontinued in April, 1980. In Table 1-2, these sections would not become acceptable until secondary treatment is installed in June, 1984.

TABLE 1-2

WATER QUALITY BENEFIT/COST ANALYSIS OF ALTERNATIVE INVESTMENT STRATEGIES

		Alternatives	Present Worth Costs ($ millions)	Conditions without Chlorination Acceptable Water Quality Sections	Present Worth Benefits ($ millions)	Benefit/Cost Ratio
Category I:		Sequence 1, A, B, D.2&4a-d	457.0	C1-C8, N1-N3, M4	328.3	0.72
		with E.1, secondary treatment	607.1	C1-C8, N1-N3, M4, BH1-BH4	408.2	0.67
I:		Sequence 2, A, B, C, D.2&4a-d	487.2	C1-C8, N1-N3, M4	328.3	0.67
		with E.2, secondary treatment	641.4	C1-C8, N1-N3, M4, BH1-BH4	408.2	0.64
I:		Sequence 3, A, B, C, D.5 (EMMA)	454.3	None	0	0
		with E.2, secondary treatment	608.5	BH2-BH4	55.9	0.09
Category II:	A.	EMMA Recommended Plan	603.0	None	0	0
	B.	EMMA with STP additions	653.3	None	0	0
Category III:	A.	No satellite plants	582.4	None	0	0
	B.	Two secondary satellites, effl. to B.H.	581.2	None	0	0
	C.	Two secondary satellites, effl. to rivers	563.0	None	0	0
	D.1	Two land treatment satellites	576.1	None	0	0
	.2	with ID.4b-d street cleaning	670.3	C1-C6, N2, N3	177.2	0.26
	.3	with land at upstream locations	670.3	C1-C6, N1-N3	199.0	0.30
	E.	One secondary satellite, effl. to B.H.	575.8	None	0	0
	F.	One secondary satellite, effl. to Nep.	564.1	None	0	0
	G.1	One land treatment satellite on Nep.	582.7	N3	23.5	0.04
	.2	with land at upstream location	582.7	N1-N3	79.0	0.14
	H.	One AWT satellite on Neponset River	597.6	None	0	0
	J.	Primary treatment, effl. to ocean	475.7	None	0	0
	K.	Primary treatment, effl. to Harbor	390.9	None	0	0

2. METHOD OF STUDY

2.1 Introduction

This case study adopted a method of analysis quite different from that of the MDC's EMMA study. The EMMA study began with estimates of future population shifts from the inner city to the suburban metropolitan area, coupled with estimates of increased per capita water use, community sewerage and wastewater production. Plans for additional plumbing requirements (interceptors, pumping stations, etc.) were then developed for transport of the projected additional wastewater flows to various alternative discharge locations in the metropolitan Boston area.

Depending upon the wastewater type and discharge location, EMMA specified treatment processes to satisfy some of the letter of the law of the Federal Water Pollution Control Act (PL 92-500). Secondary biological treatment was specified for dry weather discharges to Boston Harbor. Advanced waste treatment (secondary plus some nutrient removal) was specified for dry weather discharges to tributary rivers. Some wet weather discharges were to be detained temporarily and chlorinated before continuing to be discharged to either the Harbor or tributary rivers. The single exception to these pre-selected treatment schemes was a large scale land disposal alternative examined late in the study and discarded as unworkable.

After the selection of five seemingly arbitrary combinations of discharge locations, a preliminary, qualitative assessment was conducted of the impact of each combination on, among other things, water quality. In each case, water quality in Boston Harbor was projected to improve. No attempt, however, was made to assess whether projected improvements would be sufficient to satisfy water quality objectives; the EMMA study had no particular water quality objectives. Water quality in tributary rivers was projected to decline because of excess nutrients, viruses and toxic chlorine concentrations (EMMA Vol. 13).

The procedural analysis used in this case study has been precisely the reverse of the EMMA procedure: this study began with water quality goals and objectives (as does PL 92-500) and then progressed through the analysis to an assessment of the impact of these water quality goals upon wastewater management requirements and available water quality management strategies.

2.2 Water Quality Standards

This study began with an examination of the existing and historical water quality goals in the metropolitan Boston area, as exhibited in the Massachusetts Water Quality Standards, water quality criteria, water use classifications and the conflicting priorities for meeting those uses.

A modified system of water use classifications and water quality criteria was then proposed in an attempt to reduce the many ambiguities now present in the Massachusetts system and thereby to clarify the objectives in subsequent analytical steps. Specifically, the intents of the proposed new system were to divorce water quality criteria from wastewater effluent criteria, to eliminate entirely such unenforceable vaguenesses as "none other than of natural origin" and to delineate more precisely the conditions of satisfaction or violation of the criteria for certain key water quality parameters.

2.3 Existing Water Quality

Available data from water quality surveys, basin plans and other information sources for Boston Harbor and its three major tributaries, the Charles, Mystic and Neponset Rivers, were analyzed to develop descriptions of existing water quality and specific pollution problems in these waterways. To facilitate this and subsequent steps in the analysis, each waterway was divided into a series of individual water quality sections, the divisions being based upon locations of significant pollution discharges, major tributary inflows or diversions and relatively definable tributary drainage characteristics. For each of these sections, the critical controlling water quality parameter or combination of parameters was identified. Present and projected values for this parameter or combination then became the basis around which subsequent water quality management strategies were developed and/or analyzed for each of the water quality sections.

2.4 Pollution Sources in Metropolitan Boston

Pollutant inflows were estimated and catalogued for each section of Boston Harbor and its tributary rivers. Point source inflows were estimated from available effluent quality and flow data. Pollutants from nonpoint sources, urban stormwater and combined sewer overflows were estimated from the population, sewerage service and land use distributions as catalogued (year 1970) and as projected (year 2000) in the EMMA study. Three parameters were used in this step of the analysis as representative measures of the pollutant contributions of any given source: five-day biochemical oxygen demand (BOD); phosphorus (P) and total coliform bacteria (Coli).

2.5 Water Quality Projection Models

Simplified water quality models (mathematical equations) were developed to relate the reported water quality data in each section to the reported or estimated pollutant inflows. These models, while implicitly compatible with generally recognized physical, chemical and biological phenomena and their interactions in natural waters, explicitly were empirically designed and applied. To many professional modelers, this approach may be seen as unacceptably simple, if not naive. Others, however, will see inherent virtue, if not elegance, in this very simplicity. The approach was adopted consciously for quite specific reasons. First, it was a continuing intent of this study that its results and conclusions, as well as the methods of arriving at them, be of national as well as local applicability. All models and other methodological steps used in this study, then, were developed or selected for their capability and ease of general application. Second, the level of the analysis was concerned more with broad implications of alternative water quality management strategies than with the details and precision that will be required of subsequent engineering design. The appropriate concern at this level was with the accuracy of identifying the principal sources, or causes, of pollution and with connecting those causes with water quality effects directly and, with minimal assumptions, clearly exposed. Third, the level of sophistication of these models is consistent with the generally inadequate data base in the metropolitan Boston area. In only two areas, the Dorchester Bay section of Boston Harbor and the Charles River Basin, have there been appropriately systematic attempts to collect the water quality data necessary to describe the transitory character of urban waterways subject to pollution from intermittent sewer overflows and urban stormwater runoff. Available pollution source data for combined sewer overflows are minimal. No data whatsoever exist for separate urban stormwater sources or for nonpoint sources.

Finally, as a general strategy analysis policy, the empirical models, such as those demonstrated in this study, demand data. These models dictate clearly and explicitly the types and locations of data needed for understanding the relationships between specific pollution sources and ultimate water quality.

2.6 Pollution Control Technology Capabilities

The water quality models were used to estimate, for each water quality section, the pollution source reductions that would be necessary for the critical controlling water quality criteria to be satisfied. Pollution reduction capabilities and costs were then developed for a number of representative structural and nonstructural pollution control technologies. Control technologies considered for point source dry weather flows were conventional and expanded primary treatment, secondary treatment, advanced waste treatment and land application. Continued and expanded reliance on on-site disposal systems was examined as an alternative to the extensive regional sewering envisioned by the EMMA study. Storage and three treatment levels (primary, secondary and advanced) were examined and compared with intensive street cleaning programs for control of urban stormwater pollution. Combined sewer overflow control technologies included storage and treatment, automated sewer flushing and the detention-chlorination tanks advocated by the EMMA study and being constructed by the MDC.

Not explicitly considered in this analysis were specific control technologies for rural and suburban nonpoint sources, such as runoff from agricultural and forest lands, wetlands drainage, septic tanks and solid waste disposal sites.

2.7 Water Quality Management Strategies

A number of management strategy alternatives were then developed and examined. All alternatives were based upon EMMA study population and land use distributions projected for the year 2000. To facilitate this development and subsequent comparisons among strategy alternatives, a measure of potential water quality benefits was also developed. This measure consisted of a normalized distribution of Boston metropolitan area census tract populations according to their relative proximities to each water quality section in the metropolitan area (Battelle 1976). By coupling this measure with previous results of local willingness-to-pay surveys, a financial measure was created for comparing estimated benefits of clean (swimmable/fishable) water at any one location relative to all other locations in the Boston metropolitan area.

The first group of management strategy alternatives (Category I) considered the maximum use of existing facilities, upgraded and rehabilitated as necessary to operate as originally intended. Wastewater flow projections used for this alternative were more consistent with EPA proposed cost-effectiveness guidelines and with actual Boston area measurements than were the EMMA study projections. Management alternatives developed for this first category were based explicitly upon those pollution reductions or load limitations required to satisfy water quality criteria. Category I alternatives were grouped, then, into investment sequences designed to maximize the water quality benefits derived from each dollar of pollution control expenditure. Category I might thus be considered representative of a water quality management plan, as opposed to the recommended EMMA plan, and its modifications all focus on wastewater management.

The second management strategy (Category II) was the MDC's EMMA plan, as recommended, and also with some facilities modifications suggested by Kennedy Engineers. The third strategy (Category III) considered a series of major facilities alternatives to those recommended by the EMMA plan, as well as the elimination of the present diversion of Charles River water through Mother Brook to the Neponset. All Category II and III alternatives included the wastewater flows projected by the EMMA study. The water quality benefits associated with each of the Category II and III alternatives were then compared with their respective costs as was done with the Category I alternatives.

3. WATER QUALITY STANDARDS

3.1 Introduction

Water quality standards in general consist of three fundamental parts: (1) a system of water use class designations and a process for classifying waterways or segments of waterways according to these uses, either present or intended; (2) a delineation of the criteria intended to define the quality of water acceptable for each use class and (3) a number of definitions and general provisions intended to further clarify water quality standards and the policies for their implementation. In addition to the water use classifications described above, Section 303(d) of PL 92-500 requires an additional classification of each water segment as to whether the point source treatment levels specified in Section 301 of the Act will be adequate to satisfy the goal of the Act (swimming and fishing quality waters) or whether more stringent treatment or other actions will be necessary.

3.2 Water Use Classification in the Metropolitan Boston Area

3.2.1 Existing Classification System*

The present use classes established in 1974 by the Division of Water Pollution Control (DWPC) for the fresh waters in the Commonwealth of Massachusetts are designated alphabetically as A, B and C, where:

Class A waters are designated as sources of public water supply;

Class B waters are suitable for bathing, recreational purposes and water contact activities, are acceptable for public water supply with treatment and disinfection, are excellent fish and wildlife habitats, have excellent aesthetic values and are suitable for certain agricultural and industrial uses and

Class C waters are suitable for recreational boating and secondary water contact recreation, are suitable as habitats for wildlife and fish indigenous to the region, are suitable for certain agricultural and industrial uses, have good aesthetic values and under certain conditions are acceptable for public water supply with treatment and disinfection.*

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*Massachusetts water quality standards were revised in April 1978. See Appendix A2 for a copy of these new standards. See Section 11.2.2 for a discussion of the revisions.

In addition, there are Class B1 and C1 waters that have the same uses and water quality criteria as Classes B and C, with the exception of relaxed dissolved oxygen criteria.

The present use classes for the Commonwealth of Massachusetts salt waters are SA, SB and SC, where:

Class SA waters are of the highest quality and are suitable for bathing and other water contact activities, are suitable for approved shellfish areas and for taking shellfish without depuration, have the highest aesthetic values and are excellent fish and wildlife habitats;

Class SB waters are suitable for bathing and recreational purposes (including body contact sports), and for industrial cooling, have good aesthetic values, are excellent fish habitats and are suitable for certain shell fisheries with depuration (restricted shellfish areas) and

Class SC waters are suitable for aesthetic enjoyment, for recreational boating, for habitats for wildlife and common food and game fish indigenous to the region and are suitable for certain industrial uses.

The water quality criteria presently associated with each of the above freshwater and saltwater use classes is appended to this report as Appendix A1: Massachusetts Water Quality Standards. The present water quality standards (classifications and criteria) were scheduled to be reviewed and revised as necessary by January 1, 1977, but the revisions will probably not be made before the end of 1977 because of pragmatic and philosophical differences of opinion that have existed between the regional EPA and DWPC, and among DWPC personnel themselves, regarding the meaning and application of such standards.**

The water use classification process in Massachusetts can perhaps best be understood from the historical record. In March, 1967, the DWPC adopted a set of water quality standards, consisting of definitions of several water use classes and associated water quality criteria. Based on these standards and after public hearings, each river basin and saltwater zone in the Commonwealth was classified, usually in several sections, according to anticipated future uses. "Determination of the anticipated future uses involved considerations of present uses, public desire for other uses requiring higher water quality and some consideration of the degree of water quality improvement possible in light of technological capabilities and economic feasibility" (DWPC 1976a). That the third of these considerations received rather more consideration and the second rather less consideration than the criteria described above might indicate was revealed in a 1971 Report on the Charles River (Jobin and Ferullo 1971).

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*The grammar and punctuation of these and the salt water use class descriptions are not precisely those of the legally adopted standards, but have been modified slightly for clarification.

**See footnote on previous page.

> Classification of the Charles River
>
> On April 14, 1967, a public hearing was held relative to the classifications to be applied to the Charles River and coastal waters of Massachusetts. Over 300 people attended the meeting in Gardner Auditorium of the State House in Boston. The Director of the Division of Water Pollution Control presented the proposed classification for the Charles River, including the recent upgrading of the river to a B classification from Bridge Street in Dover to the Watertown Dam.
>
> Several spokesmen for the Legislative and Executive branches of the Commonwealth indicated their support of the proposed classification, especially the B quality in the reach above Watertown Dam. Others expressed a desire that the Lower Basin also be raised from C to B classification. Representatives of conservation groups and the League of Women Voters urged a B classification for the entire river. Petitions and letters received were unanimously in favor of raising the entire river to a B classification. At least 250 letters, 12 telegrams and several petitions asked that the entire river be classified B.
>
> The final classifications formally adopted by the Division and accepted by the Federal Government include a B classification for the entire river except for the Lower Basin and the upper reach from Milford to Medfield. The exceptions were included because no technologically feasible means were available to raise the waters to a B classification in those reaches. When such means become available, the possibility of raising the classification will be reconsidered. (emphasis added).

The presumably minor sections excepted from B classification, from Main Street in Milford to Bridge Street in Dover and the Charles River

Basin below the Watertown Dam, constitute half the entire length of the river and over 95% of its total water volume.

In April, 1974, the DWPC adopted a new set of rules and regulations that included important general provisions as well as revised water quality criteria and new use classes. These are the standards currently in force and that appear as Appendix A to this report. The significant changes to the classification definitions from the 1967 standards are as follows.

- The numerical criteria for nutrients were eliminated and replaced by two general provisions. The first prohibits new discharges of nutrients to lakes and ponds or their tributaries. The second requires that discharges containing nutrients in concentrations that encourage eutrophication or the growth of algae or weeds shall be treated to the maximum extent technically feasible.
- Modifications of the B and C classifications were established for streams where all criteria for these classifications can be met except dissolved oxygen. Class B1 criteria include all Class B criteria except dissolved oxygen, for which Class C criteria would apply. Class C1 criteria include all Class C criteria except dissolved oxygen, for which a minimum 2.0 mg/l concentration would apply.
- Coliform bacteria levels of 5,000 per 100 ml were established for Class C and Class SC waters except those waters subject to urban runoff and/or combined sewer overflows, for which no bacterial limit now exists. "It is the objective of the Division to eliminate all point and nonpoint sources of pollution and to impose bacterial limits on all waters."
- Class D was eliminated. All waters previously assigned to this class must be upgraded to at least C1. Class D waters were suitable only for power, navigation and limited industrial uses.
- An anti-degradation clause was added to the General Provisions. This provision states, in part, "except as otherwise provided

herein, no new discharge of wastewater will be permitted into any stream, river or tributary upstream of the most upstream discharge of wastewater from a municipal waste treatment facility or municipal sewer discharging wastes...." The provision requires existing discharges into thus designated antidegradation streams or segments to cease and connect to a municipal sewer, unless "such connection is not available or feasible." In the latter case, "existing discharges not connected to a municipal sewer will be provided with the highest and best practical means of waste treatment to maintain high water quality." The two exceptions to the above are:

- new municipal facilities, the discharge from which is in accordance with an approved basin plan and
- "industrial liquid coolant wastes in conjunction with the public and private supply of heat or electric power," the discharge of which conforms with a permit issued by the Division and with the water quality standards of the receiving waters.

In addition, "no new discharges of wastewater will be permitted in Class SA or SB waters" except under conditions identical to those described above for fresh waters.

For the urban waterways of metropolitan Boston, where the primary water quality problems are nutrients, coliform bacteria and lack of dissolved oxygen, the revised 1974 standards represented a downgrading of water quality criteria.

In 1976, a series of Section 303(e) Water Quality Management Plans was completed by the DWPC and presented in public hearings. These basin plans included classifications of the respective river basins according to the revised 1974 water quality standards. Some of these basin plans, furthermore, proposed upgrading various stream segments to higher future use classes than those adopted in 1967. Of the major Boston metropolitan area waters, the only Water Quality Management Plan that has been prepared has been for the upstream portion of the Charles River, from its source down to the Watertown Dam. That plan's proposed upgrading of much of the middle part of the Charles from Class C to B or B1, although enthusiastically endorsed at public hearings and in written communications has not been adopted by DWPC.

At the request of DWPC, the MDC's EMMA study, with "other supporting materials," was approved by Region I EPA as the 303(e) Water Quality Management Plan for all of Boston Harbor, the Charles River Basin and the Mystic, Neponset and Weymouth Rivers (McGlendon 1976). The use classifications designated for these waters thus remain the same as the original 1967 classifications. Although the EMMA study was the subject of a great many public hearings, the reclassification of any of the waterways affected by the proposed EMMA plan was not on the agenda of any of those hearings. The request that the EMMA study be accepted as a water quality management plan appears to have been motivated by concern for federal financing eligibility under Section 201. The approval by Region I EPA seems based upon that same concern. The EMMA study, however, is decidedly not, nor was it intended to be, a water quality management plan; it is a wastewater management plan. It is precisely the absence of any explicit consideration of water quality in the EMMA planning process that has been the most troublesome aspect of the EMMA study. The most obvious flaw is the lack of even a cursory attempt to establish the allocations for maximum daily pollution loadings to planning area waters that are specifically required by Section 303(d) of PL 92-500.

Tables 3-1 through 3-4 summarize the existing water use classifications for the Boston metropolitan waters, along with present conditions of each segment of those waters. The present condition descriptors include a designation "U", which indicates that water quality criteria for none of the accepted use classifications is being satisfied. Also indicated on these tables are the 1976 DWPC 303(d) segmentations and classifications of Boston metropolitan waters as effluent limited (EF), water quality limited (WQ) or antidegradation (AD). Effluent limited waters are those in which the application of Best Practicable Treatment (BPT) of point-source pollution discharges (secondary treatment for publicly owned treatment works) will be adequate to satisfy the water

TABLE 3-1

CHARLES RIVER BASIN (20) CLASSIFICATIONS

Segment 303(d)	Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303(d) Class Phase I	303(d) Class Phase II
1	C1	Source to Dilla St., Milford	Above 76.5	Water supply, Fish & wildlife propagation	Same	A	A	AD	AD
2		From Dilla St. to Main St., Milford	76.5-75.2	Waste assimilation, Fish & wildlife propagation, Fishing	Same & bathing	U	B	WQ	WQ
3		From Main St. to Milford STP	75.2-73.4	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	U	C*	WQ	WQ
4	C2	From Milford STP to Mine Brook	73.4-63.1	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	U	C*	WQ	WQ
5	C3	From Mine Brook to outlet of Populatic Pond	63.1-58.9	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C1	C*	WQ	WQ
6		From outlet of Populatic Pond to Stop River	58.9-51.8	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C1	C*	WQ	WQ
7	C4	From Stop River to Sugar Brook	51.8-49.8	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C1	C*	WQ	WQ
8		From Sugar Brook to Bridge Street, Dover	49.8-44.6	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C1	C*	WQ	WQ
9		From Bridge Street, Dover, to South Natick Dam	44.6-41.1	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C1	B	WQ	WQ
10	C5	From South Natick Dam to Mother Brook	41.1-26.5	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C	B	WQ	WQ
	C6	From Mother Brook to Watertown Dam	26.5-9.8	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing	Same & bathing	C	B	WQ	WQ

†DWPC Basin Number

*Charles River Basin Plan (DWPC 1976a) proposed Class B1 for these segments.

TABLE 3-1 (CONTINUED)

Segment Number 303(d)	Segment Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303 (d) Class Phase I	303 (d) Class Phase II
37(19b)[†]	C7	From Watertown Dam to Cottage Farm Bridge	9.8-3.7	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing, Cooling Water	Same	U	C	EF	EF
	C8	From Cottage Farm Bridge to Charles River Dam at Science Museum	3.7-1.2	Waste assimilation, Recreational boating, Fish & wildlife propagation, Fishing, Cooling water	Same	U	C	EF	EF
38(19b)[†]		Science Museum Dam to new dam at Warren Avenue	1.2-0.7	Fish & wildlife propagation, Fishing, Industrial processing & cooling	Same	SC	SC	EF	EF
		CHARLES RIVER TRIBUTARIES							
		Mine Brook							
11	-	Source to Franklin STP	Above 4.1	Waste assimilation, Fish & wildlife propagation	Fish & wildlife propagation, Fishing	B	B	AD	AD
12	-	Franklin STP to confluence	4.1-0.0	Waste assimilation, Fish & wildlife propagation	Fish & wildlife propagation, Fishing	U	B	WQ	WQ
		Stop River							
13	-	Source to Pondville State Hospital	Above 7.8	Waste assimilation, Fish & wildlife propagation, Fishing	Same	B1	B	AD	AD
14	-	From Pondville State Hospital to Norfolk-Walpole MCI	7.8-4.0	Waste assimilation, Fish & wildlife propagation, Fishing	Same	U	B	AD	AD
15	-	From Norfolk-Walpole MCI to confluence	4.0-0.0	Waste assimilation, Fish & wildlife propagation, Fishing	Same	C1	B	AD	AD
		Sugar Brook							
16	-	From Rt. 109, Millis, to confluence	1.6-0.0	Waste assimilation	Fish & wildlife propagation	U	B	WQ	WQ

[†] DWPC Basin Number

TABLE 3-2

MYSTIC-ABERJONA RIVER BASIN (19a) CLASSIFICATIONS

Segment Number 303(d)	Segment Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303(d) Class Phase I	303(d) Class Phase II
1	M1	Aberjona source to inlet, Mishawum Lake	18.4-15.1	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & Wildlife propagation, Fishing, Industrial cooling	U	B	AD	AD
2		Inlet to outlet, Mishawum Lake	15.1-14.8	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation Fishing, Industrial cooling	U	B	WQ	WQ
3		Outlet, Mishawum Lake to inlet, Burbank Pond	14.8-13.5	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Industrial cooling	U	B	WQ	WQ
4		Inlet to outlet, Burbank Pond	13.5-13.3	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Industrial cooling	U	B	WQ	WQ
5		Outlet, Burbank Pond to Sweetwater Brook	13.3-12.0	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Industrial cooling	U	B	WQ	WQ
6		Sweetwater Brook to inlet, Pond 4	12.0-11.6	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Industrial cooling	U	B	WQ	WQ
7		Pond 4 to Horn Pond Brook	11.6-10.3	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Industrial cooling	U	B	WQ	WQ

†DWPC Basin Number

TABLE 3-2 (CONTINUED)

Segment Number 303(d)	Segment Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303(d) Class Phase I	303(d) Class Phase II
8	M2	Horn Pond Brook to inlet, Mystic Lake	10.3-9.2	Waste assimilation, Recreational boating, Fishing, Industrial cooling	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Industrial cooling	U	B	WQ	WQ
9		Inlet to outlet, Upper Mystic Lake	9.2-8.1	Bathing, Recreational boating, Fish & wildlife propagation. Fishing	Same	C	B	WQ	WQ
10	M3	Outlet, Upper Mystic Lake to Outlet, Lower Mystic Lake	8.1-7.4	Recreational Boating, Fish & wildlife propagation, Fishing	Same & bathing	U	B	WQ	WQ
11	M4	Mystic River from Outlet, Lower Mystic Lake to Alewife Brook	7.4-6.5	Recreational boating, Fish & wildlife propagation, Fishing	Same	C	C	WQ	WQ
12		Alewife Brook to the Amelia Earhart Dam	6.5-2.0	Recreational boating, Fish & wildlife propagation, Fishing	Same	U	C	WQ	WQ
				ABERJONA-MYSTIC RIVER TRIBUTARIES†					
-	-	Hall's Brook, source to confluence		Waste assimilation	Fish & wildlife propagation, Fishing	U	B	-	-
-	-	Sweetwater Brook, source to confluence		Waste assimilation, Fish & wildlife propagation, Fishing	Fish & wildlife propagation, Fishing	C	B	-	-
1	-	Alewife Brook	entire length	Waste assimilation, Fish & wildlife propagation, Fishing	Bathing, Recreational boating, Fish & wildlife propagation, Fishing	U	B	WQ	WQ
-	-	Mill Brook	-	-	-	C	B	-	-
-	-	Horn Pond	-	Emergency water supply	Same	B	B	-	-
-	-	Malden River	-	Industrial processing & cooling waste assimilation, Recreational boating, Fishing, Fish & wildlife propagation	Same	C	C	-	-

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† DWPC Basin Number

TABLE 3-3

NEPONSET RIVER BASIN (19c) CLASSIFICATIONS

Segment 303(d)	Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303(d) Class Phase I	303(d) Class Phase II
0	N1	Above Neponset Reservoir Dam	Above 29.5	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	AD	AD
1		Neponset Reservoir Dam to outlet, Crackrock Pond Dam	29.5-28.95	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
2		Crackrock Pond Dam to Summer Street Dam, Walpole	28.95-27.33	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
3		Summer Street Dam to above Bird Machine Co. diversion dam	27.33-27.15	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
4		Above diversion dam to above Kendall Mills South Street plant dam	27.15-24.25	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
5		Above Kendall Mills South Street dam to main plant dam	24.25-23.47	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
6		Kendall Mills main plant dam to outlet, Stetson Pond Dam	23.47-22.62	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
7		Outlet, Stetson Pond Dam to outlet, Bird Pond Dam	22.62-20.75	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
8		Outlet, Bird Pond Dam to USGS, Pleasant Street, Norwood	20.75-19.2	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same and bathing	C	B	WQ	WQ
9		USGS, Norwood, to confluence with East Branch	19.2-15.8	Waste assimilation, Industrial processing & cooling	Waste assimilation, Industrial processing & cooling, Fish & wildlife propagation, Fishing	U	C	WQ	WQ

†DWPC Basin Number

TABLE 3-3 (CONTINUED)

Segment Number 303(d)	Segment Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303(d) Class Phase I	303(d) Class Phase II
10	N2	Confluence with East Branch to Truman Highway bridge	15.8-8.9	Waste assimilation, Industrial processing & cooling	Waste assimilation, Industrial processing & cooling, Fish & wildlife propagation, Fishing	U	C	WQ	WQ
11		Truman Highway bridge to confluence with Mother Brook	8.9-7.9	Waste assimilation, Industrial processing & cooling	Waste assimilation, Industrial processing & cooling, Fish & wildlife propagation, Fishing	U	C	WQ	WQ
12	N3	Confluence, Mother Brook to Hollingsworth and Vose Dam	7.9-7.0	Waste assimilation, Industrial processing & cooling	Waste assimilation, Industrial processing & cooling, Fish & wildlife propagation, Fishing	U	C	WQ	WQ
13		Hollingsworth and Vose Dam to Diamond International Dam	7.0-4.53	Waste assimilation, Industrial processing & cooling	Waste assimilation, Industrial processing & cooling, Fish & wildlife propagation, Fishing	U	C	WQ	WQ
14		Diamond International Dam to Milton Lower Falls Dam	4.53-4.2	Waste assimilation, Industrial processing & cooling	Waste assimilation, Industrial processing & cooling, Fish & wildlife propagation, Fishing	U	C	WQ	WQ

† DWPC Basin Number

TABLE 3-4

BOSTON HARBOR BASIN (19) CLASSIFICATIONS

Segment 303(d)	Number ERT	Boundary Description	Mile Points	Present Uses	Anticipated Future Uses	Present Condition	Use Class	303(d) Class Phase I	303(d) Class Phase II
26	BH1	Boston Inner Harbor Boston Inner Harbor westerly inside a line from the southerly tip of Governor's Island to Fort Independence and including the Charles, Mystic, and Chelsea (Creek) Rivers and Fort Point Channel	-	Fish & wildlife propagation, Fishing, Industrial processing and cooling	Same	SC	SC	EF	EF
27	BH2	Dorchester Bay Dorchester Bay westerly inside a line from Fort Independence to Moon Island and including the Neponset River	-	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Restricted shellfishing, Industrial processing & cooling, Waste assimilation	Same	SB, SC*	SB	EF	EF
28	BH3	Quincy Bay Quincy Bay in Quincy from Bromfield Street near the Wollaston Yacht Club northerly to buoy C "1" southeasterly to the "Willows", sometimes known as Lord's Point, on the northerly shore of Houghs Neck, Quincy	-	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Restricted shellfishing	Same & shellfishing	SB	SA	EF	EF
-	BH4, BH5	Boston Outer Harbor Boston Harbor inside a line from the southerly tip of Deer Island to Boston Lighthouse to Point Allerton in Hull except as denoted above	-	Bathing, Recreational boating, Fish & wildlife propagation, Fishing, Restricted shellfishing, Assimilation	Same	SB	SB	-	-

†DWPC Basin Number

*Present condition of Lower Neponset River is described by DWPC (1976b) as SB under Boston Harbor classification and SC under Neponset River classification.

quality criteria. The antidegradation criterion has been defined earlier. The state's criteria for water quality limited segments are clear enough:

> Water quality limited segments are those where higher degrees of treatment (than BPT) or additional controls will be required. Additional controls could include solutions to combined sewer, stormwater or nonpoint source problems (DWPC 1976b).

These criteria, however, are inconsistently applied to the waters in metropolitan Boston. All of Boston Harbor and the Charles River Basin are classified as effluent limited (EF), although they are clearly, by the above criteria, water quality limited. The Neponset and Mystic Rivers, on the other hand, do appear to be correctly classified.

The historical record of the Massachusetts water use classification process, at least in the Boston metropolitan area, is at best a record of slow and reluctant response to the legal and institutional objectives and constraints imposed by federal and state laws. There has been little, if any, evidence that the process has accounted adequately or explicitly for environmental, social or recreational objectives and/or constraints. Rather, the process seems to have been controlled exclusively by engineering judgments that (1) conventional sanitary engineering alternatives, that is, more and larger pipes and sewage treatment plants, are not sufficient to upgrade certain waters in the metropolitan area and (2) there are no other alternatives. These judgments have applied most clearly where the primary pollution problems have been urban stormwater and/or combined sewer overflows. The original 1967 classification of the Charles River Basin, and the rejection of all subsequent attempts at reclassification, is one example of the application of these judgments in the face of unanimous and large demonstrations of public support for swimming quality water and the obvious environmental, social and recreational potential of this particular body of water.

3.2.2 Proposed Classification System

For purposes of the Boston Case Study, the following simplified fresh water use classification system was adopted:

Class A waters are designated as sources of public drinking water supply;

Class B waters are suitable for bathing and water contact recreation and

Class C waters are excellent habitats for fish and wildlife indigenous to the region.

For salt waters and estuaries, the use classification system is the following:

Class SA waters are suitable for approved shellfishing areas and the taking of shellfish without depuration;

Class SB waters are suitable for bathing and water contact recreation and

Class SC waters are excellent habitats for fish and wildlife indigenous to the region.

This classification system is based upon a statement of the highest use anticipated for a given body or segment of water. With the exception of public drinking water supplies (Class A waters), the stated uses of any use class are attributed to all higher use classes as well. The Class A exception is noted because swimming is not allowed in Massachusetts public water supplies, although fishing frequently is.

For the Boston Case Study, all major Boston metropolitan waters were considered to be classified as either Class B or Class SB, except for those few presently classed as A or SA, which remained at their higher classifications. This use classification was based upon an assumption that there would be no "limiting social, technological, economic, environmental or institutional factors which preclude attainment (of these uses) in specific rivers or water bodies" (Sutton 1976).

3.3 Water Quality Criteria

3.3.1 Existing Water Quality Criteria

Water quality criteria are intended to define, in terms of a series of descriptive parameters, the quality of water judged acceptable for a given use class designation. Satisfaction of these criteria is the straightforward and only legitimate objective of water quality management planning. Massachusetts' existing (1974) water quality criteria (listed in full in Appendix A1), as those of every other state in the nation, place undue confidence in an ability to distinguish between conditions resulting from "natural origins" and those resulting from "artificial origins." Further definitional vaguenesses are introduced into the Massachusetts criteria by confusing water quality criteria with effluent limitations, through such language as "none other than . . . those amounts which may result from the discharge from waste treatment facilities providing adequate treatment." Finally, there is the classic tautological definition: "None in such concentrations that would impair any uses specifically assigned to this class."

There is no obvious water quality justification for the separation of "natural origins" from "artificial origins," or from "the discharge from waste treatment facilities providing adequate treatment" (whatever that may mean) or, for that matter, from any other conceivable origin. A given water use requires a given minimum quality of water, regardless of the origin of that quality, and it is, or ought to be, the function of the water quality criteria to define that quality as clearly and unambiguously as possible. How that quality is to be reached, or even if it is possible to be reached and/or maintained, is a matter of more appropriate concern to other steps in the system, for example, the pollution load allocation or effluent limitation process or the use classification process.

3.3.2 Recommended Water Quality Criteria

For purposes of the Boston Case Study, modified water quality criteria were adopted that attempted to reduce many of the ambiguities present in the existing Massachusetts criteria. A specific intent was to eliminate distinctions between "natural" and "artificial" origins and to divorce water quality criteria from wastewater effluent criteria. Some "natural" waters, it was recognized, may not satisfy the criteria for certain uses without, perhaps, some quite "artificial" interference. An additional intent of the recommended criteria modifications was to delineate more precisely those temporal and spatial variations within which water quality could be construed acceptable. In addition to the Massachusetts Standards, two other principal sources will be referred to in subsequent background information for the recommended water quality criteria. These are the 1968 Water Quality Criteria of the then Federal Water Pollution Control Administration (FWPCA) and the 1976 Quality Criteria for Water of the EPA. The recommended criteria are compared, for each use class, with existing Massachusetts criteria in Tables 3-5 through 3-14. Background information for the selection of criteria for the recommended water quality parameter follows.

Coliform Bacteria

Fecal rather than total coliform criteria are recommended. Since fecal coliforms are commonly 20% of the total, the recommended criteria are not numerically different from existing state criteria. The criteria recommended here are intended to clarify some of the ambiguities in the state's criteria. The median of a sample set (samples taken at the same time) is more indicative of the water quality at that time than is the arithmetic mean. An arithmetic mean, incidentally, is unable to cope statistically with too many to count (TMC) values and a log mean cannot handle either TMC or zero values. However, the mean of several sample sets collected over time probably represents the total exposures of organisms better than a median. A 30-day arithmetic mean, furthermore, allows the temporal fluctuations characteristic of rainfall influenced water quality.

For Class A waters the numerical value recommended for fecal coliforms is simply 20% of the Massachusetts criterion for total coliform bacteria. The FWPCA criterion for public water supplies suggested a fecal coliform concentration of 2,000 per 100 ml. The

TABLE 3-5

CRITERIA FOR COLIFORM BACTERIA

Existing Massachusetts Criteria for Total Coliform	Use Class	Recommended Criteria for Fecal Coliform
Not to exceed an average value of 50 during any monthly sampling period.	A	Based on a minimum of not less than five sample sets taken over a 30-day period, the arithmetic mean of the medians of the sample sets shall not exceed 10 per 100 ml.
Not to exceed an average value of 1,000 nor more than 1,000 in 20% of the samples.	B	Based on a minimum of not less than five sample sets taken over a 30-day period, the arithmetic mean of the medians of the sample sets shall not exceed 200 per 100 ml nor shall more than 10% of the samples exceed 400 per 100 ml.
None in such concentrations that would impair any usages specifically assigned to this class.*	C	The arithmetic mean during any 30-day period shall not exceed 1,000 per 100 ml.
Not to exceed a median value of 70 and not more than 10% of the samples shall ordinarily exceed 230 during any monthly sampling period.	SA	Based on a minimum of not less than five sample sets taken over a 30-day period, the arithmetic average of the medians shall not exceed 14 MPN per 100 ml with no more than 10% of the samples exceeding 43 MPN per 100 ml.
Not to exceed an average value of 700 and not more than 1,000 in more than 20% of the samples.	SB	Based on a minimum of not less than five sample sets taken over a 30-day period, the arithmetic mean of the medians of the sample sets shall not exceed 200 MPN per 100 ml nor shall more than 10% of the samples exceed 400 MPN per 100 ml.
None in such concentrations that would impair any uses specifically assigned to this class.*	SC	Shall not exceed in any 30-day period an arithmetic mean of 1,000 per 100 ml.

*No bacteria limit has been placed on Class "C" or "SC" waters because of the urban runoff and combined sewer problems which have not yet been solved. In waters of this class not subject to urban runoff or combined sewer discharges, the bacterial quality of the water should be less than an average of 5,000 coliform bacteria/100 ml during any monthly sampling period. It is the objective of the Division to eliminate all point and nonpoint sources of pollution and to impose bacterial limits on all waters.

TABLE 3-6

CRITERIA FOR COLOR AND TURBIDITY

Existing Massachusetts Criteria	Use Class	Recommended Criteria
None other than natural origin.	A	A Secchi disc shall be visible at a minimum depth of 4.0 feet or on the bottom if the water is less than 4.0 feet deep.
None in such concentrations that would impair any uses specifically assigned to this class.	B	A Secchi disc shall be visible at a minimum depth of 4.0 feet or on the bottom if the water is less than 4.0 feet deep.
None allowable in such concentrations that would impair any uses specifically assigned to this class.	C	Turbidity shall not exceed 50 JTU in warm water streams or 10 JTU in cold water streams.
None in such concentrations that would impair any uses specifically assigned to this class.	SA	A Secchi disc shall be visible at a minimum depth of 4.0 feet or on the bottom if the water is less than 4.0 feet deep.
None in such concentrations that would impair any uses specifically assigned to this class.	SB	A Secchi disc shall be visible at a minimum depth of 4.0 feet or on the bottom if the water is less than 4.0 feet deep.
None in such concentrations that would impair any uses specifically assigned to this class.	SC	A Secchi disc shall be visible at a minimum depth of 4.0 feet or on the bottom if the water is less than 4.0 feet deep.

TABLE 3-7

CRITERIA FOR CHEMICAL CONSTITUENTS

Existing Massachusetts Criteria	Use Class		Recommended Criteria
None in concentrations or combinations which would be harmful or offensive to humans or harmful to animal or aquatic life.	A	a.	Nutrients Shall not be present in concentrations greater than that which would result in an algal biomass greater than that corresponding to a chlorophyll-*a* concentration of 25 μg/l.
		b.	Total Dissolved Solids Shall not exceed 500 mg/l.
		c.	Chlorides or Sulfates Shall not exceed 250 mg/l.
		d.	Nitrate Shall not exceed 10 mg/l as nitrogen.
		e.	Other Chemical Constituents Shall not be present alone or in mixtures that will exceed 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.
None in concentrations or combinations which would be harmful or offensive to humans or harmful to animal or aquatic life or any water use specifically assigned to this class.	B	a.	Nutrients Shall not be present in concentrations greater than that which would result in an algal biomass greater than that corresponding to a chlorophyll-*a* concentration of 25 μg/l.
		b.	Other Chemical Constituents Shall not be present alone or in mixtures that will exceed 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.

TABLE 3-7 (Continued)

Existing Massachusetts Criteria	Use Class	Recommended Criteria
None in concentrations or combinations which would be harmful or offensive to human life or harmful to animal or aquatic life or any other water use specifically assigned to this class.	C	a. Nutrients Shall not be present in concentrations greater than that which would result in an algal biomass greater than that corresponding to a chlorophyll-a concentration of 25 μg/l. b. Other Chemical Constituents Shall not be present alone or in mixtures that will exceed 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.
None in concentrations or combinations that would be harmful to human, animal or aquatic life or that would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same or impair the water for any other use.	SA	a. Nutrients Shall not be present in concentrations greater than that which would result in an algal biomass greater than that corresponding to a chlorophyll-a concentration of 25 μg/l. b. Other Chemical Constituents Shall not be present alone or in mixtures that will exceed 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.
None in concentrations or combinations that would be harmful to human, animal or aquatic life or that would make the waters unsafe for fish or shellfish or their propagation, impair the palatability of same or impair the water for any other use.	SC	a. Nutrients Shall not be present in concentrations greater than that which would result in an algal biomass greater than that corresponding to a chlorophyll-a concentration of 25 μg/l. b. Other Chemical Constituents Shall not be present alone or in mixtures that will exceed 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.

TABLE 3-8

CRITERIA FOR DISSOLVED OXYGEN

Existing Massachusetts Criteria	Use Class	Recommended Criteria
Not less than 75% of saturation during at least 16 hours of any 24 hour period and not less than 5 mg/l at any time. For cold water streams, the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams, the dissolved oxygen concentration shall not be less than 6 mg/l during the season.	A	Minimum of 5.0 mg/l.
Not less than 75% of saturation during at least 16 hours of any 24 hour period and not less than 5 mg/l at any time. For cold water streams, the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams, the dissolved oxygen concentration shall not be less than 6 mg/l during the season.	B	Minimum of 5.0 mg/l.
Not less than 5 mg/l during at least 16 hours of any 24 hour period, nor less than 3 mg/l at any time. For seasonal cold water fisheries, at least 6 mg/l must be maintained during the season.	B1	--
Not less than 5 mg/l during at least 16 hours of any 24 hour period, nor less than 3 mg/l at any time. For seasonal cold water fisheries, at least 6 mg/l must be maintained during the season.	C	Minimum of 5.0 mg/l.
Not less than 2 mg/l at any time.	C1	--
Not less than 6.5 mg/l at any time.	SA	Minimum of 5.0 mg/l.
Not less than 5.0 mg/l at any time.	SB	Minimum of 5.0 mg/l.
Not less than 5 mg/l during at least 16 hours of any 24 hour period nor less than 3 mg/l at any time.	SC	Minimum of 5.0 mg/l.

TABLE 3-9

CRITERIA FOR pH

Existing Massachusetts Criteria	Use Class	Recommended Criteria
As naturally occurs.	A	Shall be in the range of 6.5 to 8.0.
6.5 to 8.0	B	Shall be in the range of 6.5 to 8.0.
6.0 to 8.5	C	Shall be in the range of 6.5 to 8.0.
6.8 to 8.5	SA	Shall be in the range of 6.8 to 8.5.
6.8 to 8.5	SB	Shall be in the range of 6.8 to 8.5.
6.5 to 8.5	SC	Shall be in the range of 6.8 to 8.5.

TABLE 3-10

CRITERIA FOR RADIOACTIVITY

Existing Massachusetts Criteria	Use Class	Recommended Criteria
None other than that naturally occurring.	A	No radionuclide or mixtures of rationuclides shall be present at concentrations greater than those specified in the USPHS Drinking Water standards or greater than the Federal Radiation Council's Radiation Protection Guides for direct consumption of fresh water and aquatic organisms.
None in such concentrations or combinations in excess of the limits specified by the United States Public Health Service (USPHS) Drinking Water Standards.	B	No radionuclide or mixtures of radionuclides shall be present at concentrations greater than those specified in the USPHS Drinking Water standards or greater than the Federal Radiation Council's Radiation Protection Guides for direct consumption of fresh water and aquatic organisms.
None in such concentrations or combinations in excess of the limits specified by the USPHS Drinking Water Standards.	C	No radionuclide or mixtures of radionuclides shall be present at concentrations greater than those specified in the USPHS Drinking Water standards or greater than the Federal Radiation Council's Radiation Protection Guides for direct consumption of fresh water and aquatic organisms.
None in such concentrations or combinations in excess of the limits specified by the USPHS Drinking Water Standards.	SA	No radionuclide or mixtures of radionuclides shall be present at concentrations greater than those specified in the USPHS Drinking Water standards or greater than the Federal Radiation Council's Radiation Protection Guides for direct consumption of marine organisms.

TABLE 3-10 (Continued)

Existing Massachusetts Criteria	Use Class	Recommended Criteria
None in such concentrations or combinations in excess of the limits specified by the USPHS Drinking Water Standards.	SB	No radionuclide or mixtures of radionuclides shall be present at concentrations greater than those specified in the USPHS Drinking Water standards or greater than the Federal Radiation Council's Radiation Protection Guides for direct consumption of marine organisms.
None in such concentrations or combinations in excess of the limits specified by the USPHS Drinking Water Standards.	SC	No radionuclide or mixtures of radionuclides shall be present at concentrations greater than those specified in the USPHS Drinking Water standards or greater than the Federal Radiation Council's Radiation Protection Guides for direct consumption of non-shellfish marine organisms.

TABLE 3-11

CRITERIA FOR SLUDGE DEPOSITS - SOLID REFUSE - FLOATING SOLIDS - OIL - GREASE - SCUM

Existing Massachusetts Criteria	Use Class		Recommended Criteria
None allowable.	A	a.	Sludge Deposits, Solid Refuse, Floating Solids: None aesthetically objectionable.
		b.	Oil and Grease: None in amounts that result in tainting, taste, odor or are aesthetically objectionable.
None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin, the maximum allowable concentration is 15 mg/l.	B	a.	Sludge Deposits, Solid Refuse, Floating Solids: None aesthetically objectionable.
		b.	Oil and Grease: None in amounts that result in tainting, taste, odor or are aesthetically objectionable.
None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin, the maximum allowable concentration is 15 mg/l.	C	a.	Sludge Deposits, Solid Refuse, Floating Solids: None aesthetically objectionable.
		b.	Oil and Grease: None in amounts that result in tainting, taste, odor or are aesthetically objectionable.
None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin, the maximum allowable concentration is 15 mg/l.	SA	a.	Sludge Deposits, Solid Refuse, Floating Solids: None aesthetically objectionable.
		b.	Oil and Grease: None in amounts that result in tainting, taste, odor or are aesthetically objectionable.

TABLE 3-11 (Continued)

Existing Massachusetts Criteria	Use Class	Recommended Criteria
None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing adequate treatment. For oil and grease of petroleum origin, the maximum allowable concentration is 15 mg/l.	SB	a. Sludge Deposits, Solid Refuse, Floating Solids: None aesthetically objectionable. b. Oil or Grease: None in amounts that result in tainting, taste, odor or are aesthetically objectionable.
None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin, the maximum allowable concentration is 15 mg/l.	SC	a. Sludge Deposits, Solid Refuse, Floating Solids: None aesthetically objectionable. b. Oil or Grease. None in amounts that result in tainting, taste, odor or are aesthetically objectionable.

TABLE 3-12

CRITERIA FOR TAINTING SUBSTANCES

Existing Massachusetts Criteria	Use Class	Recommended Criteria
See Taste & Odor and Chemical Constituents Criteria.	A	None in concentrations that individually or in combination produce undesirable flavors in the edible portions of aquatic organisms.
See Taste & Odor and Chemical Constituents Criteria.	B	None in concentrations that individually or in combination produce undesirable flavors in the edible portions of aquatic organisms.
See Taste & Odor and Chemical Constituents Criteria.	C	None in concentrations that individually or in combination produce undesirable flavors in the edible portions of aquatic organisms.
See Taste & Odor and Chemical Constituents Criteria.	SA	None in concentrations that individually or in combination produce undesirable flavors in the edible portions of aquatic organisms.
See Taste & Odor and Chemical Constituents Criteria.	SB	None in concentrations that individually or in combination produce undesirable flavors in the edible portions of aquatic organisms.
See Taste & Odor and Chemical Constituents Criteria.	SC	None in concentrations that individually or in combination produce undesirable flavors in the edible portions of aquatic organisms.

TABLE 3-13

CRITERIA FOR TASTE AND ODOR

Existing Massachusetts Criteria	Use Class	Recommended Criteria
None other than of natural origin.	A	None objectionable
None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish.	B	None objectionable
None in such concentrations that would impair any uses specifically assigned to this class, and none that would cause taste and odor in edible fish.	C	None objectionable (odor only)
None allowable.	SA	None objectionable
None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.	SB	None objectionable
None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.	SC	None objectionable (odor only)

TABLE 3-14

CRITERIA FOR TEMPERATURE

Existing Massachusetts Criteria for Allowable Temperature Increase*	Use Class	Recommended Criteria for Temperature
None other than of natural origin.	A	Shall not exceed 83°F in warm water fisheries or 68°F in cold water fisheries, nor shall the temperature rise resulting from artificial origin exceed 4.0°F.
None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.	B	Shall not exceed 83°F in warm water fisheries or 68°F in cold water fisheries, nor shall the temperature rise resulting from artificial origin exceed 4.0°F.
None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.	C	Shall not exceed 83°F in warm water fisheries or 68°F in cold water fisheries, nor shall the temperature rise resulting from artificial origin exceed 4.0°F.
None except where the increase will not exceed the recommended limits on the most sensitive water use.	SA	Shall not exceed 83°F nor shall the temperature rise resulting from artificial origin exceed 1.5°F.
None except where the increase will not exceed the recommended limits on the most sensitive water use.	SB	Shall not exceed 83°F nor shall the temperature rise resulting from artificial origin exceed 1.5°F.
None except where the increase will not exceed the recommended limits on the most sensitive water use.	SC	Shall not exceed 83°F nor shall the temperature rise resulting from artificial origin exceed 1.5°F.

*Some of the language in these Massachusetts criteria is surely unintended. It is not likely that Massachusetts intended that 83°F and 68°F temperature increases were to be in any case allowable.

Massachusetts criterion of 10 per 100 ml appears to reflect a desire to use only extremely high quality waters for public water supplies, and this local option was not changed.

For Class SA waters the numerical criterion recommended is the same as that proposed by EPA, which in turn was taken from the National Shellfish Sanitation Program. The method of determining the mean from a time series of median values is specified herein to better reflect total exposure of shellfish to pathogens.

For Class B waters the average concentration recommended is the same as the log mean value recommended by EPA. EPA criteria are also recommended for Class SB waters except the most probable number (MPN), rather than the membrane filter (MF) technique, is specified. One-to-one relationships between the MF technique and the MPN have not been found in salt waters; the MPN normally results in a higher coliform bacteria count. This difference is recognized by HEW in the National Shellfish Safety Program.

For Class C and SC waters, Massachusetts criteria indicate a desire to achieve a fecal coliform value of 1000 per 100 ml. Since there is no apparent health or welfare issue relating to fecal coliform bacteria in these use classes, the state's criterion has been adopted here. As such, the fecal coliform criteria for Classes C and SC can be considered as surrogates for other, unspecified, water quality parameters (except, of course, where effluents are chlorinated). Within the state's criteria, a numerical limit is applied only to certain Class C and SC water bodies (those without urban runoff or combined sewer problems). An exception is taken to this application in the recommended criteria, because if the criterion is desirable for some Class C or SC waters, it is desirable for all Class C and SC waters.

Color and Turbidity

For water Classes A, B, SA and SB, the color and turbidity criterion is based on the 1968 recommendation of the FWPCA. For the safety of swimmers, FWPCA recommended that a Secchi disc be visible at a minimum depth of 4 feet. For safety reasons the FWPCA also recommended that a Secchi disc be visible on the bottom in "learn-to-swim areas." Criteria proposed by EPA for color and turbidity in later publications have not included the safety recommendation of FWPCA. Reasons for not including the safety recommendations are not explained. The FWPCA indicated that administration of the recommendation might be difficult. Canadian officials and several states, however, have used Secchi disc criteria for water quality classification apparently without difficulty.

For Class C waters the FWPCA recommended that turbidity should not exceed 50 Jackson Turbidity Units (JTu) in warm water streams and 10 JTU in cold water streams, and these criteria are adopted here. These limits were primarily based on the protection of bottom fauna.

There have been no numerical values recommended by EPA or FWPCA for Class SC waters. The criterion proposed herein is based on an FWPCA observation that turbidity resulting in a Secchi disc value of less than one meter "should be regarded with suspicion and the nature of the suspended material as well as the composition of plankton determined."

Chemical Constituents

a) Nutrients (Nitrogen and Phosphorus)

Neither Massachusetts nor EPA have developed criteria for nutrients for the control of nuisance aquatic growths. At the same time there are a large number of eutrophic lakes, reservoirs and streams nationwide and in the state. Also, nutrient limitations have been placed on wastewater discharges. With such an apparent water quality implication, criteria do seem required. The difficulties associated with establishing nutrient criteria have resulted from attempts to establish individual nutrient concentration limits; this approach probably has no universal solution. Establishing individual nutrient limits is analogous to establishing separate limits for carbonaceous and nitrogenous biological oxygen demand concentrations, both of which are stream or site specific. Dissolved oxygen, however, is a fairly universal measure of water quality. Similarly, primary productivity and algal biomass are fairly universal measures of nutrient enrichment. The criteria recommended here are based upon the general observation that an algal biomass greater than that corresponding to a chlorophyll-a concentration of

25 μg/l is excessive.* Secchi disk visibilities at 4-foot depths are associated with 25 μg/l chlorophyll-a concentrations; nuisance or scum-forming algae blooms occur typically when chlorophyll-a concentrations exceed 25 μg/l. A value of 10 μg/l is often considered a eutrophic limit because the level of decomposable organic matter represented by this may result in winter fishkills in lakes and reservoirs. Consequently, the 25 μg/l criterion may need to be adjusted downward for some water bodies after more site-specific information is collected.

b) Total Dissolved Solids

Recommended criteria for Class A waters are identical to EPA's criteria for public water supplies.

c) Chloride or Sulfates

Recommended criteria for Class A waters are identical to EPA's criteria for public water supplies.

d) Nitrate

Recommended criteria for Class A waters are identical to EPA's criteria for public water supplies.

e) Other Chemical Constituents

The other chemical constituents criteria are designed to cover all potential toxicants. The general criteria recommended here are the same as the most restrictive of the EPA criteria for individually specified toxic substances. An unnecessarily onerous monitoring and analytical burden would be implicit in the establishment of individual criteria in state standards for all potential toxic chemicals. Furthermore, it does not seem advisable to be restricted only to the present list of EPA-specified substances, although the continuing EPA listings should be used as guidance. The general 0.01 of 96-hour LC_{50} criteria* may also be relaxed at some sites for some substances (for example, copper) where site-specific chemical and biological information indicates this to be advisable.

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*"Chlorophyll-a", for this purpose, is considered to be the resulting concentration from the trichromatic analytical procedure specified in Standard Methods for the Analysis of Water and Wastewaters, 14th ed., p. 1030.

Dissolved Oxygen

The dissolved oxygen criterion recommended here for all water use classes is the EPA recommended minimum of 5.0 mg/l. This criterion differs from the existing Massachusetts criteria in two respects: (1) Massachusetts permits lower dissolved oxygen concentrations in Classes B1, C, C1 and SC and (2) Massachusetts criteria include references to saturation values and diurnal variations. Since all waters are classified as at least excellent fish and wildlife habitats, and since EPA's dissolved oxygen criterion is developed for this use, all waters are recommended to have the same criterion. The state's criteria would not permit a diverse population in Classes B1, C and C1. For example, Class C1 with a 2.0 mg/l minimum is a very poor fish habitat. The state's criteria are furthermore unnecessarily complicated. The intent of the state's criteria is to include both seasonal and diurnal dissolved oxygen variations; however there is no strong evidence that such variations above a firm minimum of 5 mg/l have any fish or wildlife impact. The state's 6.0 mg/l criterion for cold water fisheries is intended as additional assurance that there will be at least 5 mg/l dissolved oxygen in the gravel interstitial water during salmonid spawning seasons; again there is no strong evidence that this would be required if the 5.0 mg/l minimum was never violated.

The dissolved oxygen requirements of marine organisms have not received the amount of study that the requirements of freshwater organisms have. EPA has not established dissolved oxygen criteria for marine waters, and FWPCA tentative recommendations were 5.0 mg/l for coastal waters and 4.0 mg/l for estuaries and tidal tributaries. Massachusetts criteria range from 3 mg/l for Class SC waters to 6.5 mg/l Class SA waters. Since all salt water use classes are excellent fish habitats, a common 5.0 mg/l value has been recommended for all marine waters. The state's 6.5 mg/l criterion for Class SA waters is more stringent than required.

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*96-hour LC_{50} is the "lethal concentration" of a substance, at which 50 percent of test organisms are killed after 96 hours of exposure. the standard water quality criteria is 1% (0.01) of this concentration.

pH

EPA criteria for pH range from 6.5 to 9.0 for freshwater aquatic life and from 6.5 to 8.5 for marine aquatic life. Existing Massachusetts criteria vary for fresh waters and marine waters but, except for Class C, are all within the EPA ranges. These internal differences in the state's criteria presumably reflect varying degrees of protection for the aquatic life. The criteria recommended here are the maximum protection ranges in the state criteria.

Radioactivity

Recommended criteria for radioactivity are the same as those recommended by FWPCA and differ only slightly from Massachusetts criteria in that the Federal Radiation Council's Protection Guides are additionally referenced.

Sludge Deposits - Solid Refuse - Floating Solids - Oil - Grease - Scum

The aesthetic aspects of the recommended criteria are considered to be effectively equivalent to both EPA and Massachusetts criteria, although the language differs somewhat. The toxic aspects of the EPA oil and grease criteria are included within the recommended criteria for other chemical constituents. The state's 15 mg/l petroleum-based oil and grease criterion has been eliminated for two reasons: (1) specifying an oil-film sampling procedure that would allow a 15 mg/l concentration to reflect an objectionable aesthetic condition is very difficult and (2) 15 mg/l of dispersed petroleum pollutants, especially soluble fractions, is indicated by the EPA criteria to be extremely toxic to certain larvae. Admittedly, the still qualitative criteria recommended for these parameters may remain administratively awkward. Aesthetic criteria become in some ways equivalent to definitions of pornography and subject to similar regulatory difficulties. It is probably, for similar reasons, not possible to do better.

Tainting Substances

The taste and odor criteria and tainting substances criteria recommended here are essentially the same as the EPA criteria, the primary difference being the elimination from the criteria of specific reference to organoleptic testing. The recommended criteria differ from the state's approach, where tainting is included within the taste and odor criteria and also within the chemical constituent criteria for marine waters; they are recommended here as a separate category. Taste and odor are aesthetic qualities associated with direct human contact, whereas tainting substances are associated with secondary contact (fish and shellfish consumption).

Temperature

The species of fish indigenous to an area is sensitive to seasonal temperature variations and to the resulting maximum and minimum temperatures. It is necessary, therefore, to constrain water temperatures below a lethal maximum while still maintaining the seasonal variation. This has led Massachusetts, as well as other states, to inject criteria for effluent limitations into the criteria for water quality. While this mixing of effluent and water quality criteria within the water quality standards is definitely undesirable, if not unworkable (effluent criteria belong in discharge permits), in the case of temperature this analysis found no better substitute.

The criteria recommended for fresh waters are similar to the existing Massachusetts criteria. The EPA criteria are based on formulas that require data not always available. The Massachusetts criteria appear to be at least as stringent as that which would result from the application of the EPA criteria formulae.

The criteria proposed for marine waters are based on Connecticut Water Quality Standards because neither Massachusetts nor EPA have established criteria for maximum temperatures. The most stringent condition in the criteria would appear to be the 1.5°F allowable temperature increase. This is slightly more stringent than the 1.8°F allowable increase in the EPA criteria.

Zone of Passage

The recommended water quality criteria would generally be required to apply, at any given time and location, throughout a minimum of 75 percent of the cross-sectional area transverse to the direction of streamflow or tidal excursion. The exceptions to this 75 percent minimum will be the criteria for sludge deposits, solid refuse, floating solids, oil and grease and odor, which will apply throughout the entire cross-sectional area. This specification is to accommodate dispersion of discharge plumes as well as accounting for water quality variations with depth in stratified waters.

4. EXISTING WATER QUALITY IN METROPOLITAN BOSTON

4.1 Introduction

To facilitate subsequent analyses and to provide more detailed water quality descriptions, the Charles, Mystic and Neponset Rivers and Boston Harbor were divided into 19 water quality sections. The boundaries of these sections were based upon changes in watercourse characteristics, locations of significant pollutant discharges, major tributaries or diversions and relatively clearly defined drainage area characteristics. With two exceptions, these section boundaries coincided with boundaries of the 1976 DWPC 303(d) segmentation and classification system. The two exceptions were both on the Charles River: DWPC's Charles River segment 10 was divided at the Mother Brook diversion into two water quality sections; the Charles River Basin (DWPC's Boston Harbor segment 37) was divided at the MDC's Cottage Farm Detention/Chlorination Station into two sections. These water quality sections and their locations are summarized in Tables 3-1 through 3-4.

4.2 Charles River

Controlling Water Quality Parameters

Nutrient concentrations (primarily phosphorus) are the controlling parameters for water quality sections C1 through C6 on the Charles River. Recent analyses of various satellite treatment plant locations by Region I EPA, using the most current version (STREAM 7) of the Massachusetts STREAM model, indicate that dissolved oxygen immediately downstream from any 5 mg/l BOD discharge to the Charles will be in violation of the proposed oxygen criterion during the 10-year, 7-day low flow design conditions. Even in the other locations, however, where dissolved oxygen concentrations are acceptable, the algal growth stimulated by high phosphorus concentrations is not. It further appears, from preliminary modeling analysis, that any control strategy resulting in acceptable phosphorus (and, therefore, algal) concentrations would also result in sufficiently low BOD concentrations that dissolved oxygen levels would be acceptable at nearly all locations. Model results indicate zero dissolved oxygen in Cedar Swamp Pond during the low flow conditions under any control strategy yet examined, although it is questionable whether there would be any water in Cedar Swamp Pond under these conditions. Coliform concentrations, similarly, would be acceptable under any rigorous phosphorus control strategy. For the Charles River Basin, sections C7 and C8, the controlling water quality parameters are coliform bacteria and optical density, the latter being comprised of background color, turbidity and algal biomass.

Section C1: Source to Milford Sewage Treatment Plant (mile 73.4)

This section includes DWPC's Charles River segments 1, 2 and 3. It begins at Echo Lake, the public water supply for the Town of Milford, where water quality is uniformly good and rapidly degrades in quality downstream to the outfall of the Milford sewage treatment plant. This section includes Cedar Swamp Pond, a shallow impoundment choked with aquatic weeds and algae, low dissolved oxygen and moderately high nutrient concentrations. Cedar Swamp Pond and the remainder of this section are subject to urban runoff and sewer overflows/bypasses from the Town of Milford. The old Milford dump and an existing sanitary landfill operation are located in this section. Color is low at the beginning and high at the end of this section and remains high the length of the river.

Section C2: Milford Sewage Treatment Plant to Mine Brook (mile 63.1)

This is DWPC's segment 4; it begins as the most seriously polluted section of the main stem Charles River, with dissolved oxygen frequently less than 1.0 mg/1, with toxic concentrations of ammonia, and concentrations of nutrients, BOD and bacteria those of a poorly disinfected secondary sewage effluent. During low flow periods, the entire flow in this section is the effluent from the Milford sewage treatment plant. Problems with subsurface disposal systems in North Bellingham have been indicated by DWPC. Sludge deposits and nuisance growths of algae and duckweed are common. Nevertheless, considerable recovery of dissolved oxygen occurs toward the end of this section, although phosphorus concentrations remain high.

Section C3: Mine Brook to Stop River (mile 51.8)

This section includes DWPC's segments 5 and 6. Pollution is primarily from the Franklin sewage treatment plant, which discharges to the Mine Brook tributary of the Charles. Medway's Broad Street sewer discharges raw sewage to Great Black Swamp in this section and there is also a minor discharge from Your Laundry in Medway. Other pollution sources are urban runoff and nonpoint sources; malfunctioning subsurface disposal systems have been reported in the Shepards Brook area of Franklin. Dissolved oxygen concentrations in this section remain moderately depressed; nutrient concentrations, particularly phosphorus, are high and nuisance algal growths occur.

Section C4: Stop River to South Natick Dam (mile 41.1)

This section includes DWPC's segments 7, 8 and 9. Point source discharges to the first two miles of this section are from the Stop River (Pondville State Hospital, Wrentham State School, Norfolk-Walpole MCI) and from Sugar Brook (National Can Corp., Cott Corp., GAF Corp., Millis sewage treatment plant); Sugar Brook received its name from the bottling company effluent composing most of its flow. Two miles further downstream, the Medfield State Hospital discharges to this section. Subsurface disposal systems in Medfield, Holliston and Natick, other nonpoint sources and urban runoff are additional sources of pollution. This section marks the transition from primarily identifiable point sources of continuous pollution along the Charles River to primarily intermittent nonpoint sources and urban runoff. Dissolved oxygen concentrations decline along the first half of this section and begin to recover at its end. Phosphorus concentrations remain high throughout the section and algae growth increases. Bacterial concentrations are very high at the Sugar Brook confluence and gradually decline downstream.

Section C5: South Natick Dam to Mother Brook (mile 26.5)

This section comprises the upstream half of DWPC's segment 10. The sources of pollution in this section are entirely urban runoff and nonpoint, with no significant point source discharges. Dissolved oxygen gradually increases; bacterial concentrations continue to decline. Phosphorus, however, remains high (averaging about 0.3 mg/l) and algal growth rates are very high. Nutrients, primarily phosphorus, are the primary water quality problem in this section. The downstream end of this section marks the diversion, through Mother Brook, of up to one-third of the flow of the Charles to the Neponset River.

Section C6: Mother Brook to the Watertown Dam (mile 9.8)

This section comprises the downstream half of DWPC's segment 10. Pollution sources are nonpoint sources and, increasingly, urban runoff. Old dump sites exist along the banks of the river in Newton and Waltham. Sewer overflows/bypasses have been noted in Waltham. Phosphorus concentrations level out at 0.2 to 0.3 mg/l in this section and summer algal growth is prolific. Although dissolved oxygen concentrations remain only moderately depressed (minimum concentrations 5 to 5.5 mg/l and average concentrations about 7 mg/l), the gradually increasing BOD and bacterial concentrations downstream indicate the increasing impact of urban runoff on water quality in this section.

Section C7: Watertown Dam to Cottage Farm Bridge (mile 3.7)

This section comprises the upstream half of DWPC's Boston Harbor segment 37. The sources of pollution in this section are entirely urban runoff and combined sewer overflows from the areas of Boston, Cambridge and Watertown upstream from the MDC's Cottage Farm Detention/Chlorination Facility. Water quality in this section suffers from high concentrations of color, turbidity, phosphorus, algae and bacteria. The anaerobic salt water layer moves into the downstream half of this section during summer low flow periods. As salinity increases in this section, freshwater algae from upstream begin to disappear and are replaced by more tolerant brackish water species.

Section C8: Cottage Farm Bridge to the Science Museum Dam (mile 1.2)

This is the downstream half of DWPC's Boston Harbor segment 37. The sources of pollution of this section are the MDC's Cottage Farm Detention/Chlorination Facility and combined sewer overflows and urban runoff from Boston, Cambridge and Somerville. The bottom half of the water in this section is an anaerobic salt water layer, in which have accumulated large concentrations of ammonia, phosphorus, exotic organic materials and hydrogen sulfide. Sludge deposits and petrochemical residues have been reported to increase along the length of this section, although the former have not been found in any water quality surveys of the section. Other than anaerobic bacteria, there are virtually no living organisms found at the bottom in this section. Visually, however, the surface water improves somewhat from that in the immediate upstream section. Color and turbidity decrease somewhat, as do algal populations. Whether the upstream color and turbidity coagulate and settle out due to the marked increase in salinity or are simply diluted by the overflowing sewage and urban runoff is not known. The algal populations, however, are known to be diminished by the salinity gradient. Before the brackish water algae from immediately upstream have grown to their limit, they too are exposed to toxic salt concentrations and are replaced by marine species toward the end of the section. The overall appearance is one of generally declining algal mass along the length of the section. The high salinity also results in lower bacterial concentrations than might otherwise be found if the Basin were entirely fresh water. Although bacterial concentrations approach those of raw sewage immediately after rainfall events, they subsequently decline three to five times faster in the salt water than they otherwise would in fresh water.

4.3 Mystic-Aberjona River System

Controlling Water Quality Parameters

Controlling water quality parameters for the Aberjona River, section M1, are dissolved oxygen, coliform bacteria and nutrients (ammonia concentrations are in excess of levels toxic to fish).

Controlling parameters for the Upper Mystic Lake, section M2, are nutrients (ammonia is still found in toxic concentrations). In the Lower Mystic Lake, section M3, the controlling surface water quality parameter becomes phosphorus; below a depth of 30 feet, the extremely noxious water quality is the direct result of the sharp salinity differential. Water quality in the Mystic River itself, section M4, is limited primarily by coliform bacteria and phosphorus concentrations.

Section M1: Source of the Aberjona River to its Confluence with Horn Pond Brook (mile 10.3)

This section is comprised of DWPC's segments 1 through 7, and includes all but the final mile of the Aberjona River. Other than two small cooling water discharges, there are no point sources of pollution in this section. Water quality, however, is poor throughout the entire section because of a variety of nonpoint sources, urban runoff and sewer overflows/bypasses. The National Polychemicals Company until recent years discharged an extremely acidic waste, with high concentrations of ammonia, nitrates, nitrites, sulfides and chlorides to a swampy area along Hall's Brook, which enters the Aberjona River two miles from its source. The Woburn Sanitary Landfill is also located in this area along Hall's Brook. An industrial park is located at the confluence of Hall's Brook and the Aberjona. An auto parts yard is located on the west bank of the Aberjona one mile further downstream. Raw sewage overflows from Stoneham into Sweetwater Brook, a tributary to the Aberjona River in this segment. Dissolved oxygen is very low for the length of the section. Nitrogen concentrations are at toxic levels; BOD and bacterial concentrations are high at all times and extremely high after rainfall events. Flow, as well as quality, rapidly reflects rainfall in this section. During the 1967 DWPC survey, flow at the USGS gauge in Winchester increased over two days from 3.3 to 20 cfs. The Aberjona most clearly demonstrates the impact of sewering and extra-basin transport on surface water flows. Because of groundwater depletion for municipal and industrial uses, and subsequent sewage discharges to the regional MDC system, flow in the Aberjona during dry weather has been observed to decrease along this section.

Section M2: Horn Pond Brook to the Outlet of Upper Mystic Lake (mile 8.1)

This section comprises DWPC segments 8 and 9. The final mile of the Aberjona includes two impoundments followed by a backwater behind the USGS gauge in Winchester before its flow into the Upper Mystic Lake. The Upper Mystic Lake has experienced a continued degradation of water quality in recent years. The nutrient-rich Aberjona River is primarily responsible for eutrophic conditions that now exist. Aquatic plants and algal blooms prevail in the summer months in the relatively shallow reaches near the inlet.

In the main body of the lake, stratification produces near-zero dissolved oxygen levels at depths greater than 15 to 20 feet in the late summer months. Surface water temperatures at this time exceed 80°F, resulting in conditions unsuitable for the habitat of game fish. In addition, 3.0 mg/l levels of ammonia-nitrogen at the surface, increasing to 6.0 mg/l at the bottom, have been recorded. These concentrations are in excess of the lethal limit for game fish. Concentrations of zinc, at levels potentially lethal to game fish, have been recorded. Analysis of samples collected on February 18, 1975, at the center hole in the main body of the lake, produced 0.18 mg/l of zinc at the surface and 0.20 mg/l at the 65-foot depth. A zinc concentration of 0.23 mg/l was found in the Aberjona River at the inlet to the lake. The Aberjona River is therefore believed to be the source of the high zinc concentrations in the lake. However, further study is needed to determine the actual source of zinc to the Aberjona River. For these reasons, and because of the small volume of water with the necessary dissolved oxygen and temperature characteristics, the Massachusetts Division of Fisheries and Game no longer stocks the Upper Mystic Lake with trout.

The large volume of water contained in the lake is displaced at an extremely slow rate in the summer months when the Aberjona River is at its lowest flow. During this time, the lake is stratified and little mixing occurs at depths greater than 30 feet. An average yearly flow of 27.0 cfs for the Aberjona River would take approximately two months to displace the volume contained in the first 30 feet. If the displacement time were calculated at the normal summer flow of 2.0 cfs, however, it would be greater than two years. The long detention time through the lake results in an observable improvement in water quality at the outlet.

Section M3: Outlet of Upper Mystic Lake to Outlet of Lower Mystic Lake (mile 7.4)

This section is DWPC's segment 10, and is the Lower Mystic Lake. The Lower Mystic Lake suffers severe water quality problems that are probably common to no other lake in the state. Prior to the construction of the Amelia Earhart Dam in 1966, the entire Mystic River and the Lower Mystic Lake were tidal waters. Saltwater intrusion in the lower levels of the Mystic River extended upstream to the Lower Mystic Lake. The bottom freshwater of the lake was many years ago displaced by the heavier saltwater which now lies stagnant and, due to the density gradient, remains unmixed with the freshwater during the spring and fall overturns. The Amelia Earhart Dam has in effect trapped the saltwater which has since gone anaerobic from the decay of organic material. Anaerobic decomposition of the bottom matter produces toxic and foul-smelling hydrogen sulfide gas. The dormant saltwater has also acted as a nutrient sink as algae populations die, settle out and decompose, thus trapping nutrients in the stagnant water. Sampling conducted at a depth of 65 feet on October 22, 1974, yielded 15 mg/l of total phosphorus and 46 mg/l of ammonia-nitrogen. The freshwater layer of the lake extends to a depth of 30 feet. The dissolved oxygen concentrations varied from 9.1 mg/l at the surface to 8.5 mg/l at 30 feet. Below this the dissolved oxygen concentration was zero to the bottom. High sulfides were found throughout the bottom saltwater layer.

During the 1967 water quality surveys, a massive blue-green algae bloom was found on the Lower Mystic Lake, probably the result of abundant phosphorus. The Lower Mystic Lake is eutrophic, as evidenced by the proliferation of algae and aquatic plants in the warm summer months.

Section M4: Mystic River from the Outlet of Lower Mystic Lake to the Amelia Earhart Dam (mile 2.0)

Water quality in the first mile of the Mystic River is that of the surface waters of the Lower Mystic Lake. One mile downstream from the Lower Mystic Lake outlet, Alewife Brook enters the Mystic. This brook carries urban runoff and combined sewer overflows from Cambridge, Arlington and Somerville. BOD, phosphorus and bacterial concentrations in the Mystic River increase steadily from this point on downstream. The remainder of the Mystic River receives urban runoff from Medford and sewer overflows/bypasses from Somerville. There are no point-source discharges to the Mystic. The Malden River enters the Mystic just upstream of the Amelia Earhart Dam. Water quality in the Malden River is similar to that in the Mystic at this point; pollution sources on the Malden River are urban runoff from Melrose, Malden, Medford and Everett. Phosphorus concentrations between 0.1 and 0.2 mg/l and nitrogen concentrations in excess of 2 mg/l result in nuisance algae and aquatic plant growth the length of the Mystic River.

4.4 Neponset River

Controlling Water Quality Parameters

For the Neponset River sections N1 and N2, the primary parameters for which concentrations result in violations of water quality criteria are dissolved oxygen, phosphorus and coliform bacteria. The necessary fractional reductions in BOD, phosphorus and coliform discharges to these sections appear to be about the same, particularly if the coliform contamination problems during the 1973 DWPC surveys are considered. Phosphorus, then, was used as the surrogate water quality control parameter in sections N1 and N2. Coliform bacteria, if the 1973 data are even close to representative, becomes the limiting water quality parameter in section N3. The necessary reductions in coliform concentrations, by any strategy other than disinfection, would appear to satisfy other water quality criteria as well.

Section N1: Neponset Reservoir to the Confluence with East Branch (mile 15.2)

This section consists of DWPC's segments 1 through 9. It contains all but one of the significant point source discharges to the Neponset River. The first discharge is to the headwaters at Neponset Reservoir from a chemical treatment plant for the Foxboro Company's plating process. Immediately downstream, at Crackrock Pond, the Foxboro State Hospital discharges effluent from an extended aeration treatment plant. Five miles further downstream, the Bird Machine Company discharges a domestic waste effluent from an extended aeration treatment plant. The Kendall Company, one mile further downstream, discharges most of its wastewater to the MDC regional system, but about 100,000 gpd of untreated industrial wastewater is still discharged to the Neponset. Four industrial effluents are discharged into Bird Pond and the next downstream mile. Bird and Son, Inc., discharges 1.2 mgd of cooling water into Bird Pond. Bird and Son Machine and Bird and Son, Granular Division, combined with a Town of Norwood surface drain, discharge turbid effluents just downstream from Bird Pond. DWPC has also noted a small industrial discharge in this area from Hollingsworth and Vose Company. Phosphorus concentrations in the Neponset Reservoir are around 0.1 mg/l and increase downstream through Crackrock Pond as does algal and aquatic weed growth. Crackrock Pond is actually a marsh, fertilized by the nutrients in the Foxboro State Hospital effluent.

Dissolved oxygen is low throughout this section in late summer; minimum concentrations are typically between 1 and 5 mg/l during the first nine miles of flow. Reaeration at the Hollingsworth and Vose dam and the turbulent downstream flow increases the dissolved oxygen concentration to above 6 mg/l at this point; this declines to about 5 mg/l downstream at the confluence with the East Branch.

Section N2: East Branch to the Confluence with Mother Brook (mile 7.9)

This section corresponds to DWPC's segments 10 and 11. After Plymouth Rubber Company's 6 mgd cooling water discharge to the East Branch, there are no other point-source discharges to this section.

Both the Blue Hills and the Neponset River Reservations are located along this section. Dissolved oxygen declines only slightly along the length of the section, due probably to the slow velocities through the Fowl Meadow Marsh, which comprises most of this section. Phosphorus concentrations remain very nearly constant throughout this section at 0.1 mg/l. DWPC has described a bank of settled solids just upstream from the Mother Brook confluence, resulting from an untreated waste discharge from Hot-Top Pavements, Inc., a cement manufacturer. No discharge data were presented.

Section N3: Mother Brook to the Milton Lower Falls Dam (mile 4.2)

This section comprises DWPC's segments 12, 13 and 14. Mother Brook joins the Neponset River at the beginning of this section. Mother Brook is a man-made canal constructed in 1640 to divert water from the Charles River to power a corn mill built at the same time, and subsequently other mills making cloth, coins, paper, carpets, lumber, leather and nails. Mother Brook is presumed to be the first man-made interbasin hydrological modification in the United States. Today, one-third of the flow of the Charles River is diverted through Mother Brook to the Neponset for flow augmentation and flood relief. DWPC has noted a wastewater discharge from L.E. Mason Company to Mother Brook, although no flow or quality data were reported. There are no point-source discharges to this section. Urban runoff, sewer overflows/bypasses and nonpoint sources become the primary pollutant contributors in this section. The sharp increases at the Mother Brook confluence in concentrations of BOD, nitrogen, phosphorus, suspended solids, bacteria and algae indicate that a primary source of Neponset River pollution at this point is the Charles River.

4.5 Boston Harbor

Controlling Water Quality Parameters

Coliform bacteria is the controlling water quality parameter for all of Boston Harbor. If chlorination of combined sewer overflows, however, was interpreted as not much more than a cosmetic approach to the contamination problem, dissolved oxygen would also become a critical parameter in the Inner Harbor, section BH1.

Section BH1: Boston Inner Harbor, Including the Mouths of the Mystic and Charles Rivers and Chelsea Creek

This section is comprised of DWPC's Boston Harbor segments 26 and 38. DWPC describes five point-source discharges to this section, four of which are thermal discharges from Bethlehem Steel, Great Atlantic and Pacific Tea Company, MBTA South Boston Power Plant and Boston Edison's L Street Power Generating Station. The fifth point source, New England Aquarium, discharges a small waste stream that is high in bacterial and organic concentrations. Overwhelmingly, though, the pollution of the Inner Harbor is from the urban storm drainage and combined sewage overflowing both directly into the Harbor and indirectly through the Charles and Mystic Rivers. Oil slicks float into the Inner Harbor from the major tanker berths along Chelsea Creek and from the fuel and gas supply depots and tank farms around the mouth of the Mystic River in Charlestown and East Boston. Water in the Inner Harbor is characterized by coliform bacteria concentrations in excess of 100,000 organism/100 ml, high turbidity and low dissolved oxygen. Heavy metals concentrations are higher here than anywhere in Boston Harbor. Average metals concentrations in the Inner Harbor are compared to those in the Outer Harbor and also to the world oceanic average in Table 4-1. Representative coliform concentrations at various locations in Boston Harbor are shown in Figure 4-1; shellfish area classifications are shown in Figure 4-2. The Boston Harbor sections are also shown on this latter figure. Few benthic organisms are found in the sediments of the Inner Harbor, which are high in heavy metals and petroleum residue concentrations. Lead concentrations in Inner Harbor sediments are shown in Figure 4-3 and throughout the Harbor in Figure 4-4. A high correlation has been found between heavy metals and volatile organic solids in Boston Harbor sediments. The distribution of volatile solids shown in Figure 4-5, then, is representative of relative metals distributions in Boston Harbor sediments as well. For comparison, metals concentrations in Boston Harbor sediments are compared in Table 4-2 with those in the relatively unpolluted North River Estuary.

TABLE 4-1

AVERAGE TRACE METALS CONCENTRATIONS IN BOSTON HARBOR SURFACE WATERS

Element	Oceanic Average* (ppb)	Outer Harbor (ppb)	Inner Harbor (ppb)
Cadmium	0.11	0.29	0.42
Chromium	0.2	3.5	2.8
Copper	0.9	4.4	6.8
Lead	0.03	4.4	11.8
Nickel	6.6	8.0	9.4
Zinc	5.0	13.9	44.0

TABLE 4-2

RANGE AND AVERAGE METALS CONCENTRATIONS IN SEDIMENTS OF BOSTON HARBOR** AND THE NORTH RIVER***

	Boston Harbor		North River Estuary	
Element	Range (ppm)	Average (ppm)	Range (ppm)	Average (ppm)
Cadmium	0.3 - 17.5	2.8	0.0 -0.9	0.45
Chromium	20.0 -427.0	164.1	4.0-23.0	13.5
Copper	8.0 -625.0	106.9	1.8-15.0	8.4
Lead	12.5 -500.0	148.7	2.0-35.0	17.5
Mercury	0.2 - 9.4	2.3	0.04-0.16	0.1
Nickel	8.0 -129.0	29.9	5.5-11.0	7.8
Zinc	32.0-1,750.0	254.2	9.0-48.0	28.5

*Source: New England Aquarium 1972

**Source: White 1972

***Source: DWPC 1971

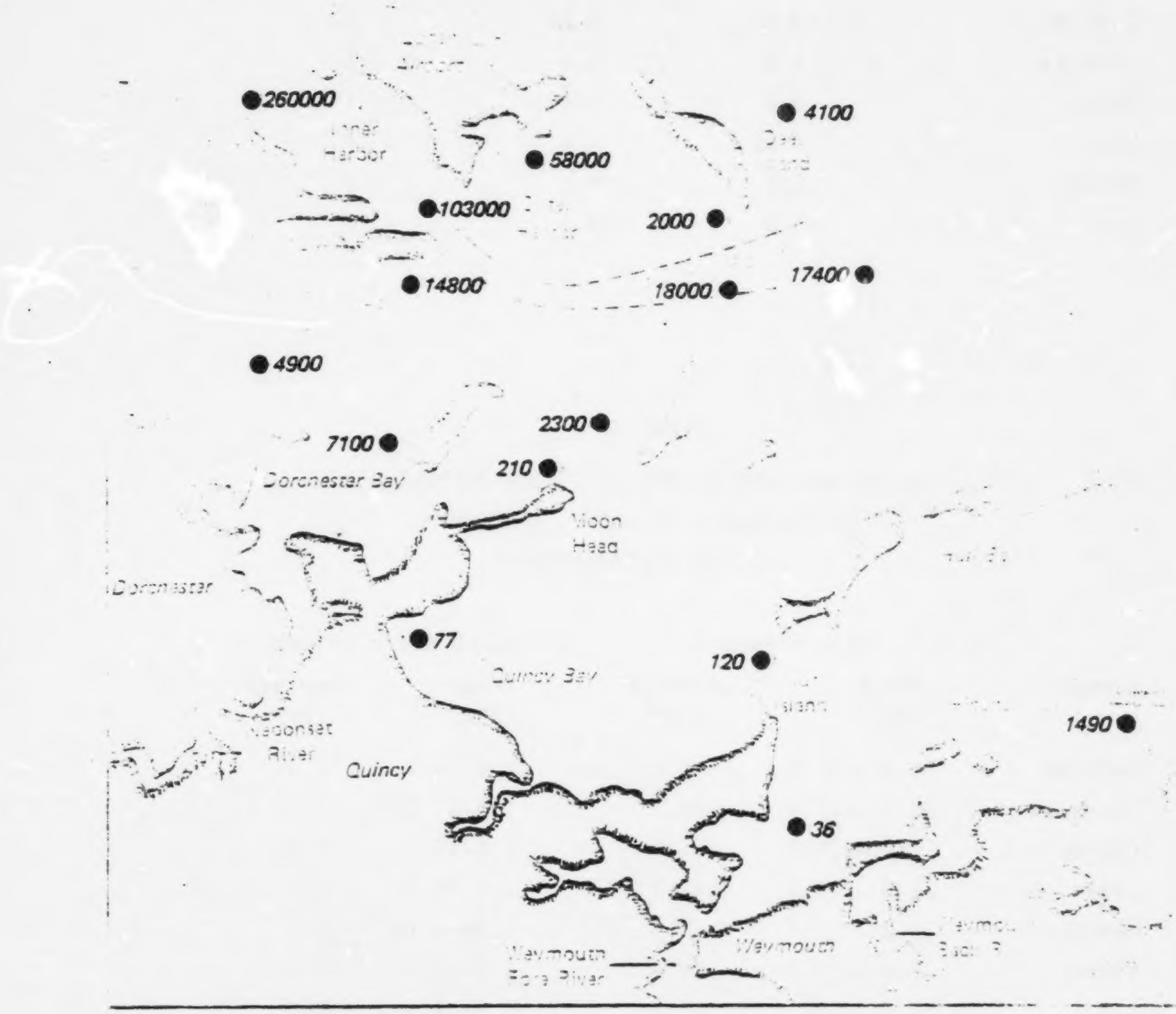
Airport
260000
Inner Harbor
58000
4100
Deer Island
103000
2000
14800
18000
17400
4900
7100
2300
210
Dorchester Bay
Moon Head
Dorchester
77
Quincy Bay
120
1490
Neponset River
Quincy
36
Weymouth Fore River
Weymouth
Weymouth Back River

Figure 4-1 Total Coliform Concentrations (numbers/100ml) in Boston Harbor, 1972 (New England Aquarium 1972)

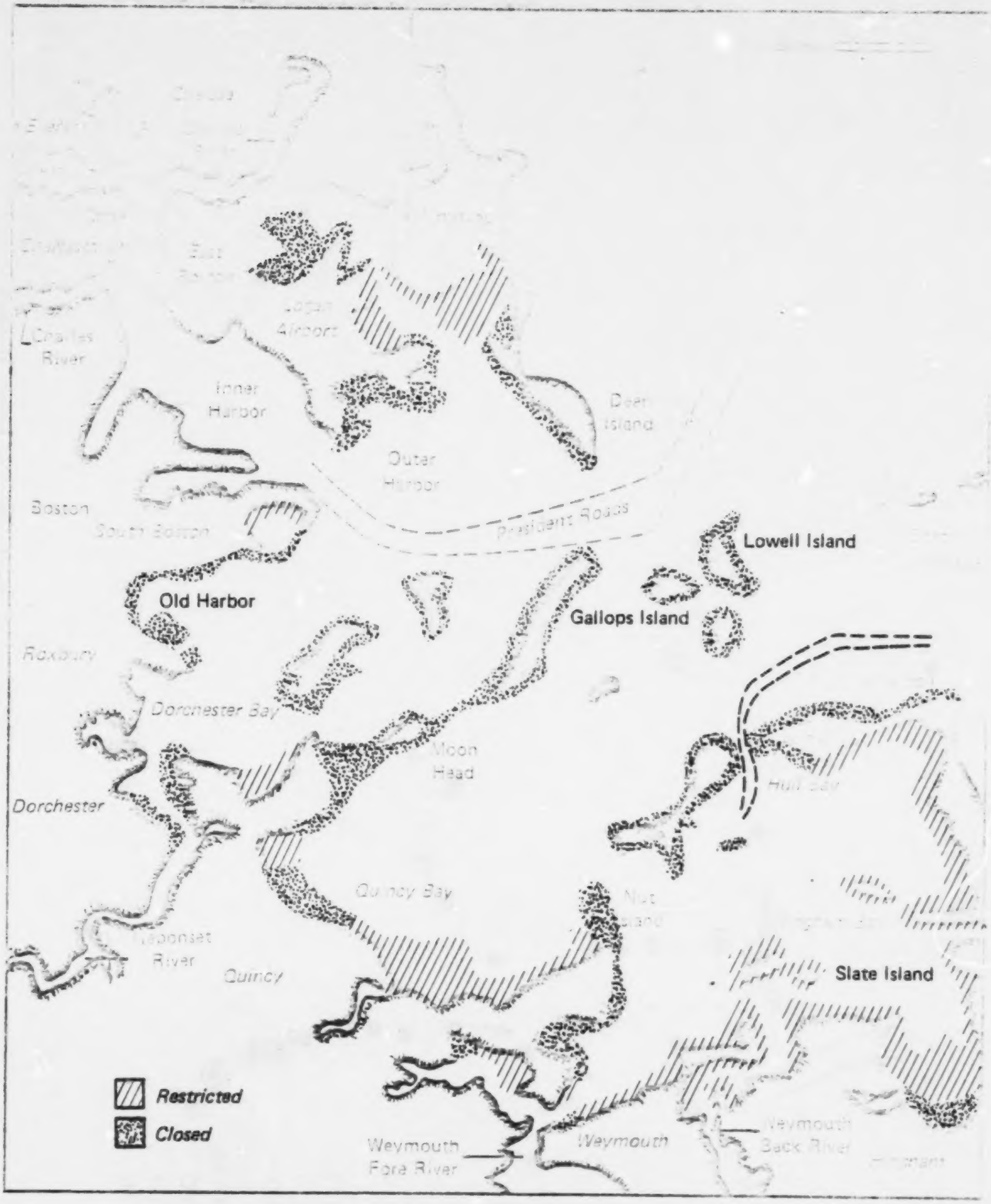
Chelsea
East Boston
Charles River
Logan Airport
Inner Harbor
Deer Island
Outer Harbor
Boston
South Boston
President Roads
Lowell Island
Old Harbor
Gallops Island
Roxbury
Dorchester Bay
Moon Head
Dorchester
Hull Bay
Quincy Bay
Nut Island
Neponset River
Quincy
Slate Island
Restricted
Closed
Weymouth
Weymouth Fore River
Weymouth Back River

Figure 4-2   Shellfish Area Classifications in Boston Harbor, 1975
(Massachusetts Food and Drug Administration 1975)

705130a

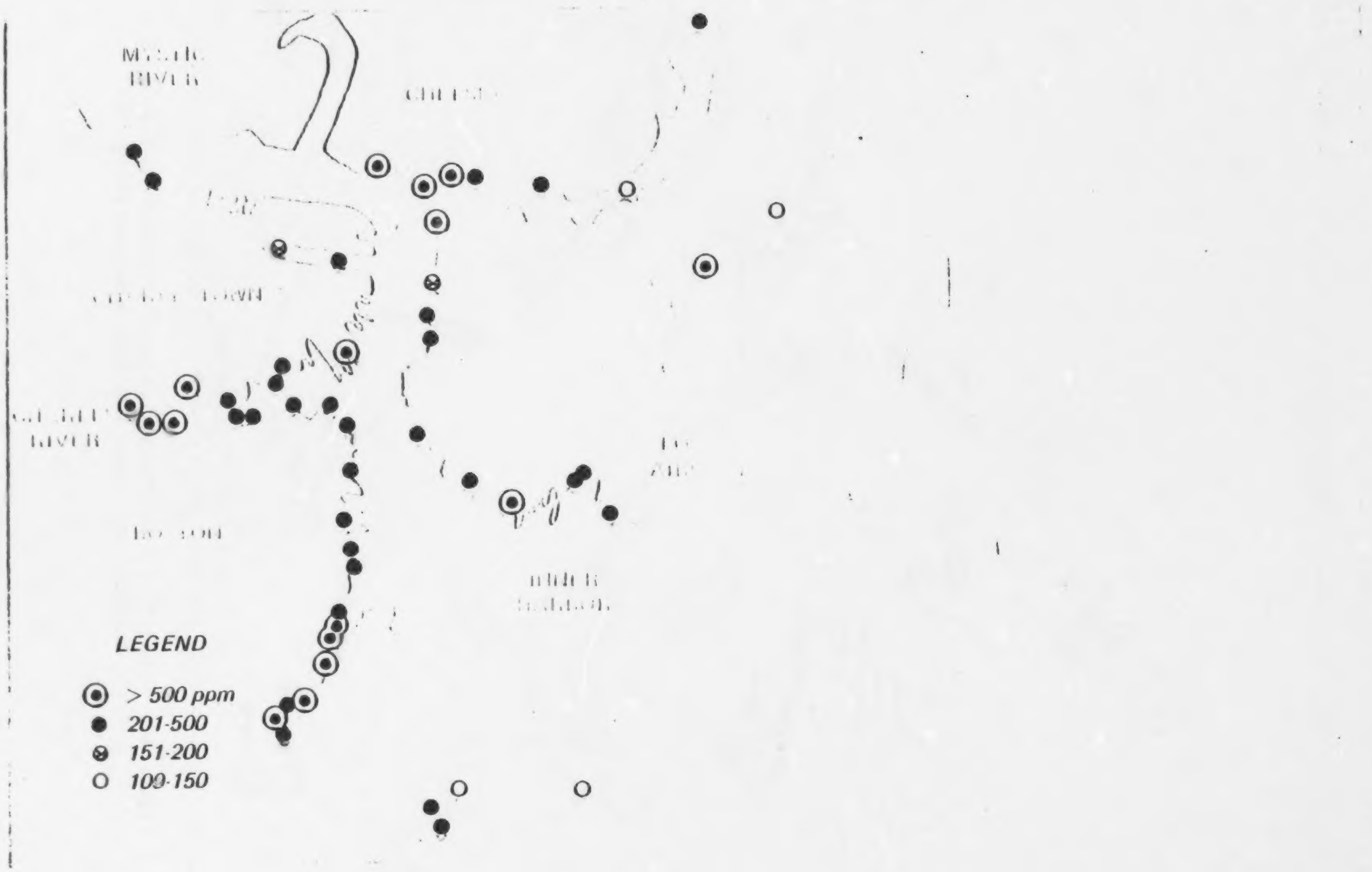
MYSTIC
RIVER
CHELSEA
CHARLESTOWN
CHARLES
RIVER
BOSTON
INNER
HARBOR
LEGEND
⦿ > 500 ppm
● 201-500
⊗ 151-200
○ 109-150

Figure 4-3 Lead Concentrations in Sediment in Inner Harbor (DWPC 1972)

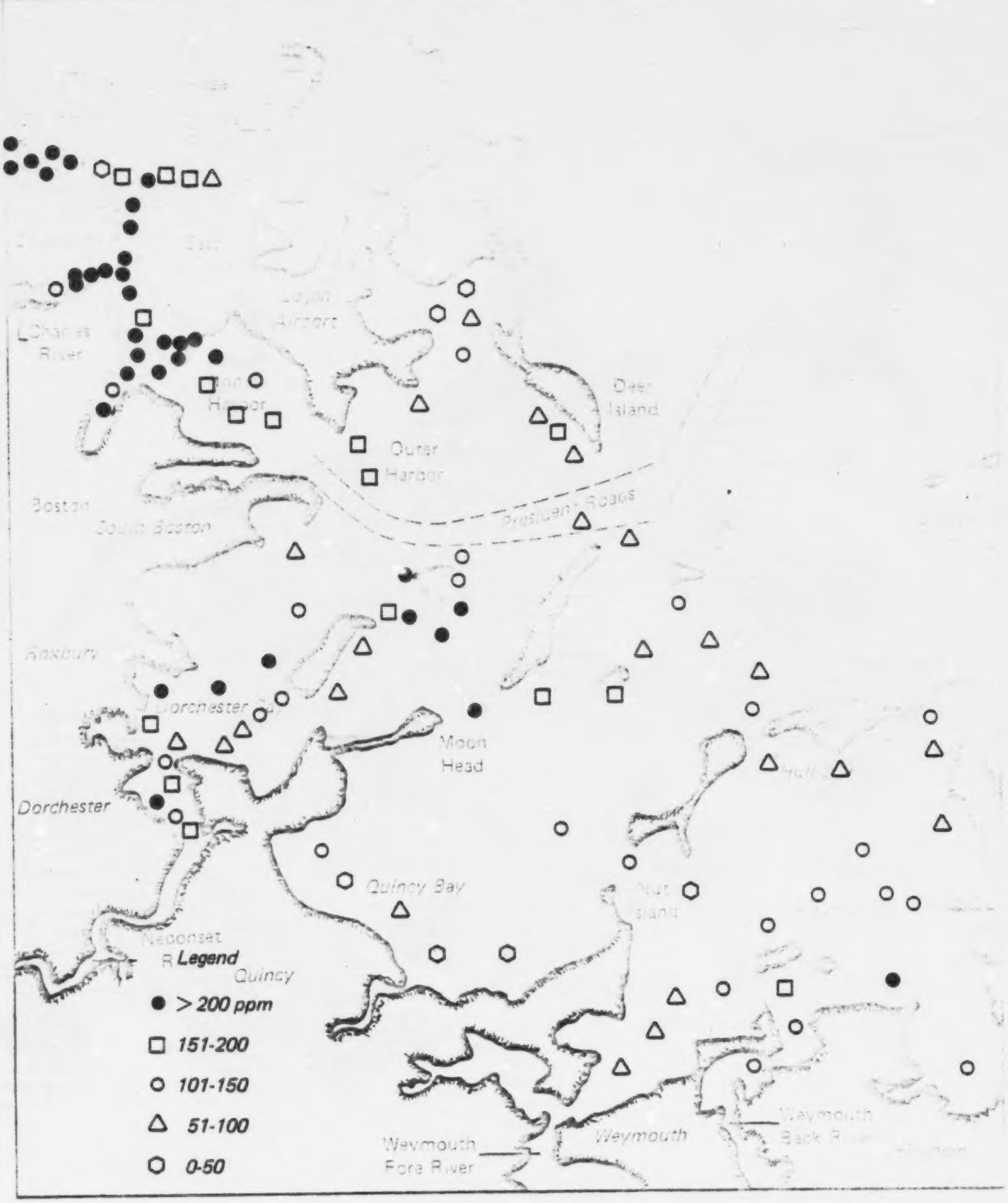
Charles River
Logan Airport
Deer Island
Inner Harbor
Outer Harbor
Boston
South Boston
President Roads
Roxbury
Dorchester Bay
Moon Head
Dorchester
Hull
Quincy Bay
Nut Island
Neponset R
Legend
Quincy
● > 200 ppm
☐ 151-200
○ 101-150
△ 51-100
⬡ 0-50
Weymouth Fore River
Weymouth
Weymouth Back River

Figure 4-4 Lead Concentrations in Boston Harbor Sediments (White 1972)

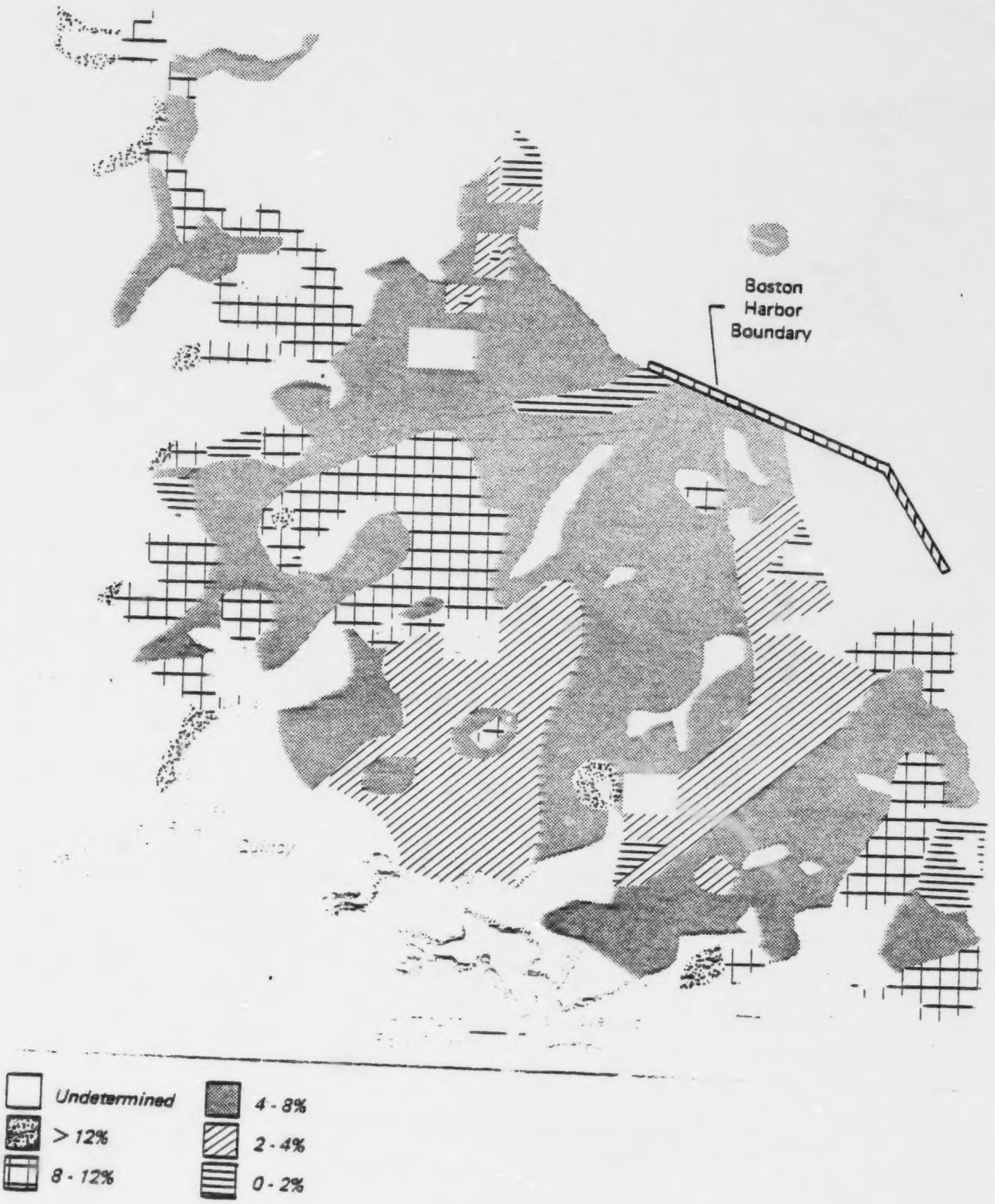
Boston
Harbor
Boundary
Quincy
Undetermined
> 12%
8 - 12%
4 - 8%
2 - 4%
0 - 2%

Figure 4-5 Percent Volatile Solids in Boston Harbor Sediments

Section BH2: Dorchester Bay, including the mouth of the Neponset River

This section is equivalent to DWPC's Boston Harbor segment 27. Sources of pollution of this section are combined sewer overflows, urban stormwater runoff and continuous sewage discharges from the blocked Port Norfolk branch sewer. The five major public bathing beaches nearest to Boston inner city residents are located in this section. Bacterial concentrations, particularly in the areas nearest the mouth of the Neponset River, exceed Massachusetts swimming quality criteria during and for sometime after rainfall events, although they remain typically less than 10% of those found in the Inner Harbor.

Section BH3: Quincy Bay

This section is equivalent to DWPC's Boston Harbor segment 28. The principal pollution source in Quincy Bay is stormwater runoff from the City of Quincy, although untreated sewage from Moon Island flows into the bay if discharged on an incoming tide. The effluent from the Nut Island sewage treatment plant is also discharged along the seaward edge of Quincy Bay. A major public bathing area is located at Wollaston Beach in this section, as are restricted shellfishing areas. Bacterial concentrations in Quincy Bay routinely satisfy the Massachusetts swimming quality criterion for marine waters, but do exceed the unrestricted shellfishing criterion. By other measures, water quality is presently acceptable in this section.

Section BH4: Boston Outer Harbor

The Deer Island treatment plant outfall, the largest single point source in the metropolitan Boston area, is located in President Roads at the seaward edge of this section. Sludge from both the Deer and Nut Island treatment plants is also discharged into President Roads on outgoing tides. Bacterial concentrations are consistently in violation of the Class SB water quality criterion throughout most of this section. The source of these high bacterial concentrations, however, seems as much the untreated sewage overflows to Boston Inner Harbor as the chlorinated Deer Island effluent. When Deer Island is not chlorinating, however, this situation is reversed and the Deer Island effluent is the primary source of bacteria (and other associated pathogens) in the Outer Harbor and a major contributor to other sections of the Harbor as well.

5. POLLUTANT LOADING DISTRIBUTIONS

5.1 Land Use and Sewer Service Distribution Patterns

Current (year 1970) and projected (year 2000) land use and sewerage service distributions were developed for each community in the Charles, Mystic and Neponset River and Boston Harbor basins as the necessary data base for estimating pollutant loads generated in the Boston Metropolitan area. These distributions are tabulated in Appendix B for each of the tributary communities. The data organization format for these distributions is illustrated in Figure 5-1. To develop this data base, numerous sources were reviewed. Much of the planning and engineering data contained in the EMMA report were directly usable. However, because of inconsistencies in the various EMMA volumes and differences between the data presented and data needs for this study, some additional calculations were necessary. The following discussion describes these calculations and the factors that made them necessary.

Unsewered Communities and Communities Served Only By Separate Sewers

Land use and sewer service distribution data were derived from five volumes of the EMMA study as well as from two additional reports on Boston area wastewater facilities. These data sources were:

- EMMA Study, Technical Data Vol. 1, Planning Criteria;
- EMMA Study, Technical Data Vol. 2, Engineering Criteria;
- EMMA Study, Technical Data Vol. 5, Land Oriented Wastewater Utilization Concept;
- EMMA Study, Technical Data Vol. 7, Combined Sewer Overflow Regulation;
- EMMA Study, Technical Data Vol. 8, Urban Stormwater Management;
- Process Research, Inc. December 1974. A Study of Pollution Control Alternatives for Dorchester Bay, Commonwealth of Massachusetts Metropolitan District Commission, and

MUNICIPAL DATA FORMAT

Town/City: ______________ Year: 1970 2000

Total Area (acres) _______ Population: _________ _________

A. Sewer Service (population)

1. Separate Sanitary
2. Combined
3. Unsewered
4. Total Sewered Population

B. Urban Runoff Areas (acres)

1. Separate Storm Sewers
    a. Residential
    b. Commercial
    c. Industrial
    d. Other
    e. Total Storm Sewer Area
2. Combined Sewers
    a. Residential
    b. Commercial
    c. Industrial
    d. Other
    e. Total Combined Area

C. Non-Point Source Areas (acres)

1. Agriculture
2. Forest
3. Wetlands
4. Mining/Disposal
5. Recreation
6. Construction
7. Total Non-Point Area

Figure 5-1 Municipal Data Format

- Process Research, Inc. August 1972. Combined Sewer Overflows to the Charles River Basin, Massachusetts Division of Water Pollution Control.

Total areas and populations for each community (for both 1970 and 2000) were extracted directly from Technical Data Vol. 1, Appendix L of the EMMA study. For towns served only by separate storm and/or sanitary sewers, the distribution of sewered and unsewered populations was that described in EMMA, Vol. 2, Table 3-3. The distributions of urban land uses into "commercial," "residential," "industrial" and "other" were calculated from data in EMMA, Vol. 1, Appendix L. The three EMMA industrial categories were first combined into one single category. The total acres of street and highway surfaces were then distributed in proportion to the residential, commercial and industrial areas. "Extensive institutional" acres were equated with the "other" category. The relationships between the urban runoff categories listed in Figure 5-1 and the EMMA categories in EMMA, Vol. 1 are described by the following equations:

Figure 5-1 Category = EMMA Categories

$$\text{Residential} = \text{Net Residential}\left(1 + \frac{\text{Streets \& Highways}}{\text{Used + Extensive Inst.}}\right)$$

$$\text{Commercial} = \text{Net Commercial}\left(1 + \frac{\text{Streets \& Highways}}{\text{Used + Extensive Inst.}}\right)$$

$$\text{Industrial} = (\text{Net Indust'l: Mfg} + \text{Net Indust'l: Non Mfg.} + \text{Extensive Indust'l})\left(1 + \frac{\text{Streets \& Highways}}{\text{Used + Extensive Inst.}}\right)$$

$$\text{Other} = \text{Extensive Inst.}$$

The precise definition of each EMMA category can be found in EMMA, Vol. 1. The "residential," "commercial," "industrial" and "other" categories in Figure 5-1 account for all the urban developed land in each town. The remaining EMMA categories, VACANT (AVAIL) and RESTRICT OPEN SPACE, were equated with those nonsewered areas contributing pollutants by nonpoint sources, that is, Part C of Figure 5-1.

The distributions of nonpoint source areas into their various land use components were figured according to Table 4 in EMMA, Vol. 5. Unfortunately, the data for nonurban land in Volume 5 did not agree with the data in Volume 1. Furthermore, the total acreages for each town were not the same in the two volumes. The Volume 5 land use areas were therefore corrected (LUcor) to reflect the total areas of nonurban land previously derived from Volume 1 by the relationship:

$$\text{LUcor} = \text{Land Use Area (Vol.5)} \times \frac{\text{\%NonUrban Land (Vol. 1)}}{\text{\%NonUrban Land (Vol. 5)}}$$

where the different nonurban land use components were agricultural, forest, wetlands, mining/disposal and recreation. In this way, the relative distributions of nonurban land uses remained approximately the same as those reported by the Corps of Engineers, but the total nonurban land areas were adjusted to equal the VACANT and RESTRICTED OPEN SPACE categories in EMMA, Vol. 1. There is evidence, incidentally, that forested areas are overestimated and wetland areas underestimated in the Corps' distributions (DWPC 1976a).

Communities Served By Combined Sewers

Five cities in the Metropolitan Boston area are served in part by combined sewer systems: Boston, Cambridge, Brookline, Somerville and Chelsea. For this study, these communities were divided according to their storm and combined sewered drainage areas among the Charles, Mystic, Neponset and Boston Harbor basins. That portion of the sewerage of the city of Boston draining to the Charles River is Allston/Brighton and those areas tributary to the Boston Marginal Conduit, Stony Brook and the Muddy River. Brookline was also included with the Boston drainage to the Charles River. The portion of Boston sewerage draining to the Neponset River includes separated areas in Mattapan, Hyde Park and Roxbury. The combined areas draining to the Neponset River estuary were included for this study in the Dorchester Bay drainage area, where their primary water quality impact is felt. The additional Dorchester Bay drainage area is that tributary to the Dorchester Interceptor and the south branch of the South Boston Interceptor. The remainder of Boston was considered to drain to the Boston Inner Harbor; this area includes Charlestown, East Boston, that area tributary to the north branch of the South Boston Interceptor and portions of downtown Boston. All of Chelsea was considered tributary to Boston Inner Harbor.

Cambridge was divided for the study between drainage areas tributary to the Charles and the Mystic River basins. All combined areas in Cambridge were included in the Charles River basin; these included areas tributary to the MDC's Cottage Farm Detention/Chlorination Facility and the sewers in Lowell and Binney Streets. The portion of Somerville tributary to the Charles River basin was included in the Cambridge tabulations. The remainder of Somerville was considered to be tributary to the Mystic River Basin.

Once the populations served by separate and combined sewers were determined, the urban land use distributions were calculated for each sewer service type. Total acres of urban residential, commercial, industrial and other land uses were determined by the same procedure used for unsewered or separate sewered communities. These areas were then distributed between the combined and separate services in proportion to the respective populations served by each type of service.

Existing and Projected Land Use and Population Distributions

Projections of future (year 2000) land uses and total populations were also based on EMMA, Vol. 1. If an increase in urban land was indicated, all nonpoint source area components were reduced by an equal percentage, except for recreation, which was assumed to remain constant. Sewered and unsewered population projections were those taken from EMMA, Vol. 2. For cities served by combined sewers, it was assumed that the ratio of combined to separate sewered areas would be the same as the ratio of combined to separate sewered populations.

Land use patterns for each of the nineteen water quality sections in the metropolitan Boston area were developed for the years 1970 and 2000 by distributing the individual community land use areas into each water section in direct proportion to the fraction of the total community acreages tributary to the respective water sections. The resulting aggregated land use patterns for each water section are tabulated in Appendix C. The 1970 patterns were assumed in the subsequent analysis to represent existing (1975) conditions.

5.2 Pollutant Loadings Distributions

Aggregated pollutant loadings distributions were computed by multiplying each land use area by an estimated annual average pollutant loading factor. For developed urban areas, pollutant loading factors for urban stormwater runoff were estimated using the methods developed recently at the University of Florida for the Stormwater and Combined Sewer Overflow Technology Branch of the EPA (Heany, Huber and Nix 1976; Heany and Nix 1977). The basic stormwater pollutant loading factors for the Boston area (43 inches annual precipitation) are listed below.

POLLUTANT LOADING FACTORS FOR URBAN STORMWATER RUNOFF

(lbs/acre-year)

	Pollutant			
Land Use	N	P	BOD	Total Coliforms*
Residential	5.6	2.2	34.4	0.04
Commercial	12.9	4.3	223.6	0.09
Industrial	12.0	4.3	52.0	0.09
Other	2.6	0.6	4.7	0.01

Loading factors for nitrogen (N) and BOD were directly from Heany et al. Those for phosphorus (P) were five times those used by Heany et al., to more closely simulate phosphorus concentrations reported for urban stormwater runoff (EMMA, Vol. 8; APWA 1977).** Loading factors for coliforms were estimated by back calculation from reported stormwater concentrations of 10^4 to 10^6 organisms per 100 ml (see, for example, EMMA Vol. 8, Table 6). Heany et al. multiply the above loading factors by a population density function that increases approximately with the square root of population density, from 0.142 for zero population or "other" land uses to 2.76 for a residential population density of 100/acre. The population density function is set equal to 1.0 by Heany et al. for commercial and industrial land uses. That procedure was also followed in this analysis, although the scatter in the data base used by Heany et al. makes the procedure far from convincing.

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*One pound of coliforms is equivalent to about 4×10^{14} organisms.

**See Section 11.4.2 of this report for further discussion of this assumption.

Pollutant loading factors for combined sewer overflows were estimated by adding to the stormwater loading factors, as computed above, a fraction of the dry weather flow of sewage pollutants assumed to deposit in the sewers during dry weather for subsequent resuspension and overflow during wet weather events.* The dry weather flow of sewage pollutants were assumed to be those listed below.

TYPICAL POLLUTANT LOADINGS IN SANITARY SEWAGE
(lbs/capita-year)

N	P	BOD	Total Coliforms
6.4	1.2	62.1	0.3

These are all conventional textbook values. See, for example, Fair, Geyer and Okun 1966. Water and Wastewater Engineering, John Wiley and Sons, New York. The loading factors for the pollutants deposited in the pipes during dry weather flow were obtained by multiplying the per capita loadings listed above by population densities and by the fraction assumed to be deposited. This fraction was generally assumed to be 0.108, based upon data collected in the Dorchester Bay area (Process Research, Inc. 1974).

For nonpoint source runoff, the pollutant loading factors assumed were based largely on the annual nitrogen and phosphorus loadings estimated by Shannon and Brezonik (1972) and by Uttormark et al. (1974). BOD loadings were estimated to be three times the nitrogen loading values (Midwest Research Institute 1975). Loading factors for unlined landfills and refuse dumps were developed from leachate compositions reported by PedCo Environmental Engineers (1976) and by Wegman (1974), with an assumed leachate rate in the Boston area of 16 inches per year. These nonpoint loading factors are summarized below.

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*The portions of dry weather sewage flow in the system that overflow during the overflow event are not included in these computations. Combined sewer overflow loadings are thus underestimated in Tables 5-1 through 5-6 by about 2 to 5%. These portions of dry weather flows are, however, included in the control strategy models.

POLLUTANT LOADINGS FACTORS FOR NONPOINT SOURCES

(lbs/acre-year)

Land Use	Pollutant		
	N	P	BOD_5
Agriculture	7	0.4	21
Forest	2	0.1	6
Wetlands	3	0.4	9
Landfills (unlined)	80	17.0	240
Recreation	8	0.2	24
Areas served by septic tanks*			
Immediate	1.24	0.07	3.7
Remote	0.50	0.01	1.5

Current (1970) point source loadings to Boston Harbor and tributaries were those tabulated in the DWPC series of reports (Part B-Wastewater Discharge Data 1975). Projected point source loadings for the year 2000 from all EMMA area alternative facilities were developed by Kennedy Engineers. Projected loadings from peripheral municipal treatment plants in the Boston Metropolitan area were estimated from flow projections in EMMA, Vol. 2 and the effluent characteristics of treatment plant types as tabulated below.

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*Units are lb/person-year; 4.3 persons per septic tank assumed.

TYPICAL EFFLUENT CHARACTERISTICS

Pollutant	Treatment Plant Type			
	Primary	Secondary	AWT	Land
BOD, mg/l	120	30	5	3
SS*, mg/l	120	30	5	7
N, mg/l	30	25	20	3
P, mg/l	10	5	1	0.05
Total Coliforms/100ml				
Unchlorinated (Lund 1975)	10^6	10^4	200	negl.
Chlorinated	1,000**	1,000	negl.	negl.

Average daily BOD, phosphorus and total coliform loadings estimated for each of the 19 water quality sections are summarized in Tables 5-1, 5-2, and 5-3, respectively, for the 1970 population and land use distributions and 1975 point source discharge data. Coliform loadings from nonpoint sources and from chlorinated effluents were assumed negligible in Table 5-3. The first and second rows of figures in the combined sewered areas represent the fractions of overflow loadings originating from street surfaces and sewer deposits, respectively. Point source figures in parentheses for sections N3, BH1 and BH2 are inflows from Mother Brook, the Charles and Mystic Rivers, and the Neponset River respectively.

BOD, phosphorus and total coliform loadings projected for the year 2000 for all water quality sections are summarized in Tables 5-4, 5-5 and 5-6. These loadings include all those from EMMA-recommended facilities except those for combined sewer overflows. To provide a consistent baseline for comparisons of subsequent alternatives, no overflow controls were included in these tables. The two satellite AWT facilities, however, were included, as well as the two secondary treatment

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*Suspended solids

**Cum grano salis

TABLE 5-1

BOD_5 LOADING DISTRIBUTIONS (lb/day), YEAR 1970

Basin Section	Urban Stormwater				Combined Sewer Overflows				Nonpoint Sources								Point Sources	Total Load
	R	C	I	T	R	C	I	T	A	F	W	M/D	R	O	ST	T		
Charles																		
C1	150	107	55	312				-	40	101	15	53	4	-	9	222	1	535
C2	56	59	36	151				-	42	45	7	95	3	-	24	216	670	1,037
C3	324	378	198	900				-	317	325	32	154	15	-	90	933	1,900	3,733
C4	601	692	283	1,486				-	325	492	61	281	26	-	150	1,335	1,126	3,947
C5	450	500	96	1,106				-	47	99	19	26	18	-	44	251	-	1,357
C6	1,744	1,915	293	3,953				-	125	217	60	102	85	-	161	750	-	4,703
C7	567	488	109	1,165	102 299	86 138	34 141	222 578	-	-	-	-	121	-	-	121	-	2,086
C8	738	839	223	1,801	423 1,459	318 674	90 522	831 2,655	-	-	-	-	204	-	-	204	-	5,491
Mystic																		
M1	588	394	233	1,215				-	55	77	22	108	20	-	63	345	-	1,560
M2	199	51	10	260				-	5	16	4	-	7	-	-	32	-	292
M3	587	214	57	858				-	16	28	16	21	19	-	10	110	-	968
M4	762	400	139	1,301	98 322	61 123	33 174	192 619	9	25	15	62	48	-	11	170	-	2,282
Neponset																		
N1	416	416	354	1,187				-	142	216	26	274	18	-	84	760	58	2,005
N2	616	584	458	1,658				-	115	223	40	248	51	-	110	787	217	2,662
N3	709	378	74	1,161				-	15	39	5	14	50	-	23	146	(1,200)	2,507
Boston Harbor																		
BH1	213	127	260	600	241 416	391 399	330 888	962 1,703	-	-	4	3	143	-	-	150	(6,000)	9,415
BH2	229	213	70	513	165 608	112 308	47 342	324 1,258	2	9	3	16	111	-	1	142	(1,400)	3,637
BH3	152	89	61	302	-	-	-	-	4	13	4	30	3	-	-	54	(*)	356
BH4	79	55	14	148	-	-	-	-	1	-	2	17	10	-	-	30	(•)	178

*BOD from Nut Island STP discharging in vicinity of Section BH3 = 149,000 lb/day.

•BOD from Deer Island STP discharging in vicinity of Section BH4 = 439,000 lb/day.

Key:

R = residential	A = agricultural	R = recreation
C = commercial	F = forest	O = other
I = industrial	W = wetlands	ST = septic tanks
T = total	M/D = mining/disposal	T = total

TABLE 5-2

TOTAL PHOSPHORUS LOADING DISTRIBUTION (lb/day), YEAR 1970

Basin Section	Urban Stormwater				Comb. Sewer Overflows				Nonpoint Source Runoff							Point Sources	Total
	R	C	I	T	R	C	I	T	A	F	W	M/D	R	ST	T		
Charles																	
C1	9.44	3.35	4.55	17.30				-	0.76	1.68	0.67	3.75	0.03	0.06	6.95	0.02	24.27
C2	3.50	1.85	3.00	8.35				-	0.80	0.75	0.31	6.73	0.03	0.16	8.78	84.00	101.13
C3	20.25	11.80	16.35	48.40				-	6.04	5.42	1.42	10.91	0.13	0.60	24.52	78.04	150.96
C4	37.55	18.80	23.40	79.75				-	6.19	8.20	2.71	19.90	0.22	1.00	38.22	33.80	151.77
C5	28.15	17.50	7.95	53.60				-	0.90	1.65	0.84	1.84	0.15	0.29	5.67	-	59.27
C6	109.00	59.85	24.20	193.05				-	2.38	3.62	2.67	7.23	0.71	1.07	17.68	-	210.73
C7	35.45	15.25	9.00	59.70	6.40 5.78	2.70 2.67	2.80 2.72	11.90 11.17	-	-	-	-	1.01	-	1.01	-	83.78
C8	46.15	26.20	18.45	90.80	26.45 28.19	9.95 13.02	7.45 10.09	43.85 51.30	-	-	-	-	1.70	-	1.70	-	187.65
Mystic																	
M1	36.75	12.30	19.25	68.30				-	1.05	1.28	0.98	7.65	0.17	0.42	11.55	-	79.85
M2	12.45	1.60	0.85	14.90				-	0.10	0.27	0.18	-	0.06	-	0.61	-	15.51
M3	36.70	6.70	4.70	48.10				-	0.30	0.47	0.71	1.49	0.16	0.07	3.20	-	51.30
M4	47.65	12.50	11.50	71.65	6.15 6.22	1.90 2.38	2.75 3.36	10.80 11.96	0.17	0.42	0.67	4.39	0.40	0.07	6.12	-	100.53
Neponset																	
N1	26.00	13.00	29.25	68.25				-	2.70	3.60	1.16	19.41	0.15	0.56	27.58	7.61	103.64
N2	38.50	18.25	37.85	94.60				-	2.19	3.72	1.78	17.57	0.43	0.34	26.03	3.63	124.26
N3	44.30	11.80	6.10	62.20				-	0.29	0.65	0.22	0.99	0.42	0.33	2.90	(72)	137.10
Boston Harbor																	
BH1	13.30	3.95	21.50	38.75	15.05 8.04	12.20 7.71	27.25 17.16	54.50 32.91	-	-	0.18	0.21	1.19	-	1.58	(200)	327.74
BH2	14.30	6.65	5.80	26.75	10.30 11.75	3.50 5.95	3.90 6.61	17.70 24.31	0.04	0.15	0.13	1.13	0.93	0.01	2.39	(90)	161.15
BH3	9.50	2.80	5.05	17.35				-	0.08	0.22	0.18	2.13	0.03	-	2.64	(*)	19.99
BH4	4.95	1.70	1.15	7.80				-	0.02	-	0.09	1.20	0.08	-	1.39	(+)	9.19

*P from Nut Island STP discharging in vicinity of Section BH3 = 2900 lb/day.

+P from Deer Island STP discharging in vicinity of Section BH4 = 8700 lb/day.

Key:

R = residential
C = commercial
I = industrial
T = total

A = agricultural
F = forest
W = wetlands
M/D = mining/disposal

R = recreation
O = other
ST = septic tanks
T = total

TABLE 5-3

TOTAL COLIFORMS (lb/day), YEAR 1970

Basin Section	Urban Stormwater				Comb. Sewer Overflows				Total
	R	C	I	T	R	C	I	T	
Charles									
C1	0.19	0.07	0.09	0.35					0.35
C2	0.07	0.04	0.06	0.17					0.17
C3	0.40	0.24	0.33	0.97					0.97
C4	0.75	0.38	0.47	1.60					1.60
C5	0.56	0.35	0.16	1.07					1.07
C6	2.18	1.20	0.48	3.86					3.86
C7	0.71	0.30	0.18	0.19	0.13 1.45	0.05 0.67	0.06 0.68	0.24 2.80	4.23
C8	0.92	0.52	0.37	1.81	0.53 7.05	0.20 3.26	0.15 2.52	0.88 12.83	15.52
Mystic									
M1	0.73	0.25	0.38	1.36					1.36
M2	0.25	0.03	0.02	0.30					0.30
M3	0.73	0.13	0.09	0.95					0.95
M4	0.95	0.25	0.23	1.43	0.12 1.56	0.04 0.60	0.05 0.84	0.21 3.00	4.64
Neponset									
N1	0.52	0.26	0.58	1.36					1.36
N2	0.77	0.36	0.76	1.89					1.89
N3	0.89	0.24	0.12	1.25					1.25
Boston Harbor									
BH1	0.27	0.08	0.43	0.78	0.30 2.01	0.24 1.93	0.54 4.29	1.08 8.23	10.09
BH2	0.29	0.13	0.12	0.54	0.21 2.94	0.07 1.49	0.08 1.65	0.36 6.08	6.98
BH3	0.19	0.06	0.10	0.35					0.35
BH4	0.10	0.03	0.02	0.15					0.15

*One pound of coliforms is equivalent to about 4 x 10^{14} organisms.

Key:

R = residential
C = commercial
I = industrial
T = total

A = agricultural
F = forest
W = wetlands
M/D = mining/disposal

R = recreation
O = other
ST = septic tanks
T = total

TABLE 5-4

BOD$_5$ LOADING DISTRIBUTIONS (lb/day), YEAR 2000

Basin Section	Urban Stormwater				Comb. Sewer Overflows				Nonpoint Source Runoff							Point Sources	Total
	R	C	I	T	R	C	I	T	A	F	W	M/D	R	ST	T		
Charles																	
C1	191	150	64	405					36	92	14	47	4	7	200	-	605
C2	72	80	41	193					38	41	7	87	3	6	182	157	532
C3	563	566	230	1,359					266	273	26	251	15	78	909	375	2,643
C4	1,141	910	346	2,397					238	366	45	256	26	153	1,084	164	3,645
C5	623	641	121	1,385					30	62	12	14	17	20	155	1,300	2,840
C6	2,244	1,984	376	4,604					82	132	39	59	88	43	443	-	5,047
C7	549	471	109	1,129	110 319	86 128	36 144	232 591					120	-	120	-	2,072
C8	650	1,124	194	1,968	376 1,168	423 818	83 423	882 2,409					215	-	215	-	5,474
Mystic																	
M1	728	539	258	1,525					37	53	17	70	20	4	201	-	1,726
M2	224	20	13	257					4	13	3	0	6	-	27	-	284
M3	633	189	72	894					10	21	14	14	23	5	87	-	981
M4	735	274	175	1,184	82 250	34 56	40 176	156 482	10	24	14	60	69	-	177	-	1,999
Neponset																	
N1	737	579	361	1,677					98	150	18	188	18	45	517	37	2,231
N2	928	872	484	2,284					83	162	30	183	50	30	538	1,217	4,039
N3	720	297	100	1,117					13	33	4	11	67	18	146	(2,400)	3,663
Boston Harbor																	
BH1	204	99	335	638	164 282	276 325	237 740	677 1,347	-	-	4	3	203	-	210	(6,000)	8,872
BH2	265	198	80	543	188 625	108 225	71 390	367 1,240	2	9	3	15	66	1	96	(1,400)	3,646
BH3	168	78	60	306					4	12	4	30	3	-	53	(*)	359
BH4	55	30	15	100					4	-	5	45	10		63	(+)	163

*BOD from Nut Island discharging in vicinity of Section BH3 = 30,200 lb/day.

+BOD from Deer Island discharging in vicinity of Section BH4 = 83,200 lb/day.

Key:

R = residential
C = commercial
I = industrial
T = total

A = agricultural
F = forest
W = wetlands
M/D = mining/disposal

R = recreation
O = other
ST = septic tanks
T = total

TABLE 5-5

TOTAL PHOSPHORUS LOADING DISTRIBUTION (lb/day), YEAR 2000

Basin Section	Urban Stormwater				Comb. Sewer Overflows				Nonpoint Source Runoff							Point Sources	Total
	R	C	I	T	R	C	I	T	A	F	W	M/D	R	ST	T		
Charles																	
C1	11.94	4.69	5.29	21.92					0.69	1.53	0.62	3.33	0.03	0.05	6.25	-	28.17
C2	4.50	2.50	3.39	10.39					0.72	0.68	0.31	6.16	0.03	0.04	7.94	31.46	49.79
C3	35.19	17.69	19.00	71.88					5.06	4.55	1.16	17.78	0.13	0.52	29.20	75.00	176.08
C4	71.31	28.44	28.60	128.35					4.53	6.10	2.00	18.13	0.22	1.02	32.00	32.80	193.15
C5	38.94	20.03	10.00	68.97					0.58	1.03	0.53	0.99	0.14	0.13	3.40	260.00	332.37
C6	140.25	62.00	31.07	233.32					1.56	2.20	1.73	4.18	0.73	0.29	10.69	-	244.01
C7	34.31	14.72	9.01	58.04	6.88 6.16	2.68 2.47	2.98 2.78	12.54 11.42					1.00		1.00	-	83.00
C8	40.63	35.13	16.02	91.78	23.50 22.57	13.22 15.81	6.86 8.17	43.58 46.55					1.79		1.79	-	183.70
Mystic																	
M1	45.50	16.84	21.32	83.66					0.70	0.88	0.76	4.96	0.17	0.03	7.50	-	91.16
M2	14.00	0.63	1.07	15.70					0.08	0.22	0.13	-	0.05	-	0.48	-	16.18
M3	39.56	5.91	5.95	51.42					0.20	0.35	0.62	0.99	0.19	0.03	2.38	-	53.80
M4	45.94	8.56	14.46	68.96	5.13 4.83	1.06 1.08	3.30 3.40	9.49 9.31	0.19	0.40	0.62	4.25	0.58	-	6.04	-	93.80
Neponset																	
N1	46.06	18.09	29.84	93.99					1.86	2.50	0.80	13.32	0.15	0.30	18.93	5.51	99.50
N2	58.00	27.25	40.00	125.25					1.58	2.70	1.33	12.96	0.42	0.20	19.19	213.60	338.85
N3	45.00	9.28	8.27	62.55					0.25	0.55	0.18	0.78	0.56	0.12	2.43	(360)	425
Boston Harbor																	
BH1	12.75	3.09	27.69	45.53	10.25 5.45	8.63 6.28	19.58 14.30	38.46 26.03	-	-	0.18	0.21	1.69	-	2.08	(200)	310.10
BH2	16.56	6.19	6.61	29.36	11.75 12.08	3.38 4.34	5.87 7.54	21.00 23.96	0.04	0.15	0.13	1.06	0.55	0.01	1.94	(90)	166.26
BH3	10.50	2.44	4.96	17.90					0.08	0.20	0.18	2.11	0.03	-	2.60	(*)	20.50
BH4	3.44	0.94	1.23	5.61					0.08	-	0.22	3.19	0.08	-	3.57	(*)	9.18

Key:

R = residential
C = commercial
I = industrial
T = total

A = agricultural
F = forest
W = wetlands
M/D = mining/disposal

R = recreation
O = other
ST = septic tanks
T = total

TABLE 5-6

TOTAL COLIFORMS (lb/day), YEAR 2000

Basin Section	Urban Stormwater				Comb. Sewer Overflows				Total
	R	C	I	T	R	C	I	T	
Charles									
C1	0.24	0.09	0.11	0.44					0.44
C2	0.09	0.05	0.07	0.21					0.21
C3	0.70	0.36	0.38	1.44					1.44
C4	1.43	0.57	0.57	2.57					2.57
C5	0.78	0.40	0.20	1.38					1.38
C6	2.81	1.24	0.62	4.67					4.67
C7	0.69	0.29	0.18	1.16	0.14 1.54	0.05 0.62	0.06 0.70	0.25 2.86	4.27
C8	0.82	0.70	0.32	1.84	0.47 5.65	0.26 3.95	0.14 2.04	0.87 11.64	14.35
Mystic									
M1	0.91	0.34	0.42	1.67					1.67
M2	0.28	0.01	0.02	0.31					0.31
M3	0.79	0.12	0.12	1.03					1.03
M4	0.92	0.17	0.29	1.38	0.10 1.21	0.02 0.27	0.07 0.85	0.19 2.33	3.90
Neponset									
N1	0.92	0.36	0.60	1.88					1.88
N2	1.16	0.55	0.80	2.51					2.51
N3	0.90	0.19	0.16	1.25					1.25
Boston Harbor									
BH1	0.26	0.06	0.55	0.87	0.21 1.37	0.17 1.57	0.39 3.57	0.77 6.51	8.15
BH2	0.34	0.12	0.13	0.59	0.24 3.02	0.06 1.09	0.12 0.02	0.42 4.13	5.14
BH3	0.21	0.05	0.10	0.36					0.36
BH4	0.07	0.02	0.02	0.11					0.11

Key:

R = residential
C = commercial
I = industrial
T = total

A = agricultural
F = forest
W = wetlands
M/D = mining/disposal

R = recreation
O = other
ST = septic tanks
T = total

plants in Boston Harbor. Peripheral area treatment plants were assumed in these tables as AWT, or equivalent, facilities discharging directly to upstream rivers. In the upper Charles River, these facilities were projected to serve the following communities.

Section	Communities	EMMA Flows, mgd	
C2	Milford		3.77
C3	Franklin	3.78	
	Medway	0.98	
	Wrentham	1.18	
	Holliston	1.38	
	Bellingham	1.68	
			9.00
C4	Medfield	2.08	
	Millis	1.86	
			3.94
C5	Middle Charles Satellite		31.0

Present wastewater discharges to the upper Neponset River were assumed to discharge AWT or equivalent effluents at their present locations, in addition to the 25.2 mgd EMMA satellite AWT facility.

6. RELATIONS BETWEEN POLLUTION SOURCES AND WATER QUALITY

6.1 Introduction

For this analysis, a number of water quality models were developed to relate water quality measurements to observed and estimated sources of pollution, and subsequently to project the impacts of alternative pollution abatement strategies on future water quality in the Boston metropolitan area. All of the models were intentionally simple and limited in their properties. The level of model sophistication should be dictated by the adequacy of the data base and, with the exception of two locations, Dorchester Bay and the Charles River Basin, the available data base in metropolitan Boston is not adequate for any but very crude models. Some will argue that, without far better and more extensive data, not even the simple models employed here can be rationalized.

The argument for more and better data than now exist in the Boston area cannot be disputed, particularly for the recognized primary problems in urban Boston: combined sewer overflows and stormwater runoff. In the course of a 2-year, $2 million wastewater management study ending with a recommendation for an additional expenditure of nearly a billion dollars of public funds, not one sample of water or wastewater was collected, examined or analyzed. Nevertheless, if it is desired to upgrade the quality of water by reducing the sources of pollution of the water, some framework for logically relating pollution sources to water quality needs to be found. The mathematical models employed in this analysis provide that framework. They are necessarily crude at this stage. With additional and more appropriate data they would be refined, better calibrated and verified with local conditions.

It may be useful to emphasize what function mathematical models perform in water quality research. They are needed to estimate the magnitudes of the source reductions likely to be necessary to achieve water quality goals. They are needed to compare, in a consistent format, the relative water quality impacts of alternative pollution control strategies. The modeling capability for detailed prediction of temporal and spatial hydrodynamics and the fates of individual chemical and biological species in a body of water would be of certain scientific, and mathematical, interest. What is not so certain, however, is that this very detailed capability would result in a commensurate increase in the necessary decision-making information beyond that provided by much simpler models.

With this introduction, the models developed and used in this analysis are described below in terms of their general properties. Specific mathematical details are provided in Appendix D.

6.2 Upper Charles River Nutrient Model*

Phosphorus was modeled as the limiting nutrient in the upper Charles. The downstream fate of a given phosphorus loading to the Charles was considered to be represented by first order decay kinetics; that is, the rate at which phosphorus naturally disappears from Charles River waters is in direct proportion to the amount of phosphorus available. A number of physical, chemical, and biological removal mechanisms are conventionally described by first order kinetics, although no particular mechanistic interpretation was intended by this model. It was based solely upon empirical observation. The decay rate constant best fitting the available data and phosphorus loading estimates was 0.1 day^{-1} (base e). A given phosphorus load would be diminished by 10% in one day's downstream travel time, by 50% in a week and by 90% in 23 days.

The phosphorus decay model considered diffuse stormwater and nonpoint sources, as well as point source loadings and converted these loadings to downstream mass fluxes and concentrations. Flow rates and travel times through each of the Charles River water quality sections were estimated according to the Massachusetts STREAM Model for the Charles (DWPC 1976), which assumes base flows at any location to be proportional to upstream drainage area, uses USGS flow data from Charles River Village (Q_{CRV}) as the calibration point and then adds sewage treatment plant effluents to all downstream base flows.

Phosphorus data from the 1973 DWPC water quality surveys were converted to mass fluxes along the Charles, using the STREAM Model flow computations, and are displayed in Figure 6-1. Also shown on this figure are phosphorus fluxes computed by the first order phosphorus decay model, using the phosphorus loadings from Table 5-2 and the STREAM

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*See Section 11.4.2 of this report for detailed criticisms and discussion of this model.

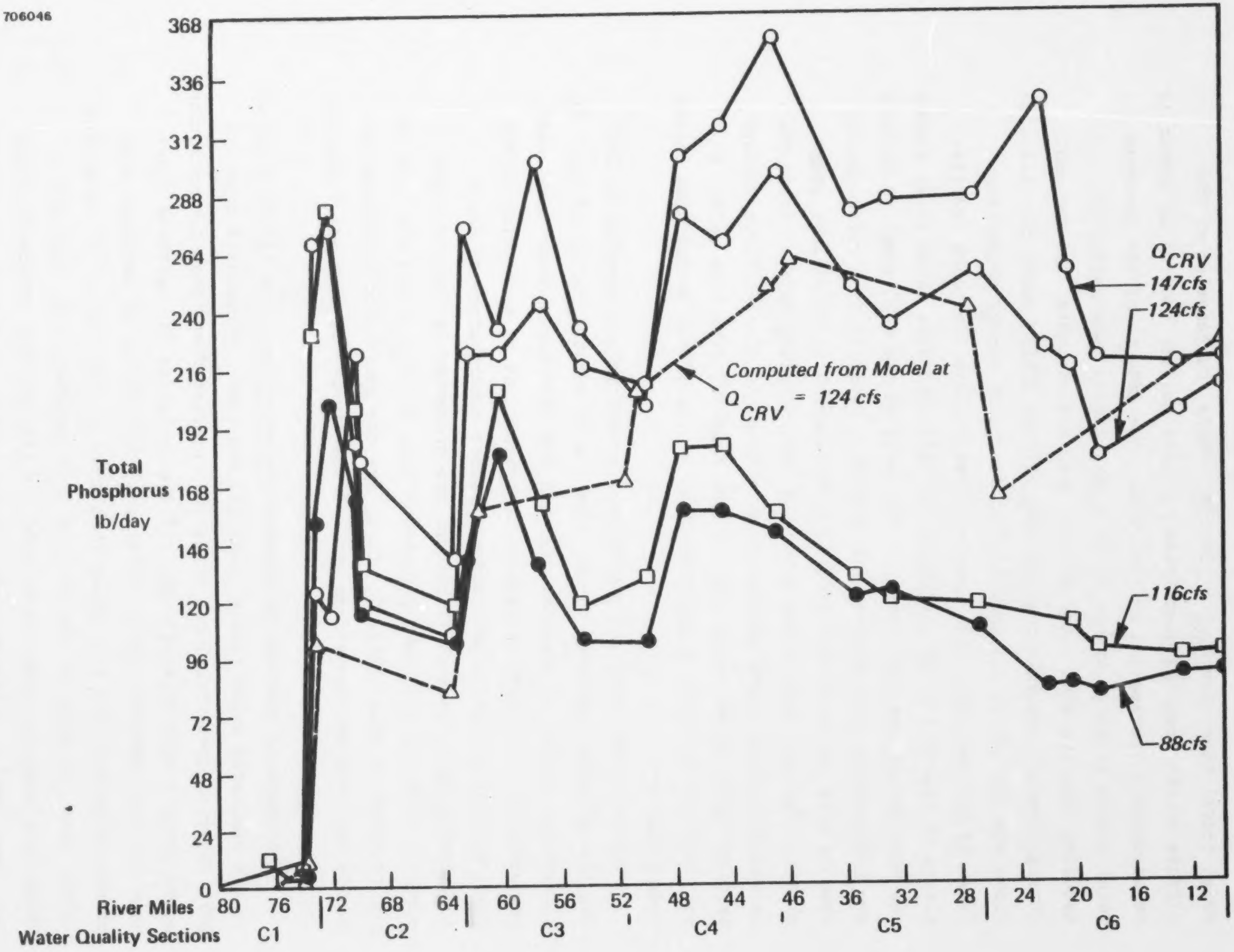

Figure 6-1 Phosphorus Fluxes in Charles River, 1973 DWPC Data

Model travel times for Q_{CRV} = 124 cfs. While the behavior of the diffuse source loadings downstream of water quality section C3 appear to be adequately represented by this model, the impacts of the upstream point source loadings appear to be significantly underestimated. Assuming that the DWPC water quality data are reliable, the two most straightforward explanations are that (1) the STREAM Model flow calculations are too low or (2) DWPC's estimated point source phosphorus loadings are too low. USGS Charles River Village flow data are displayed in Figure 6-2 for the summer of 1973 (Aberjona River flows during the same period are also shown). The dates of the DWPC sampling periods are indicated on this figure with circles. Reported flow rates can be seen to have varied 2- and 3-fold at the Charles River Village gauge within a few days before and after the DWPC sampling dates. Since the calculated travel times between river source and Charles River Village averaged about three weeks for the four sampling date flow rates, a reliable distribution of upstream flows by the STREAM method does indeed seem precarious.

On the other hand, the phosphorus concentrations reported by DWPC for the upstream treatment plants seem low by about a factor of two. An alternative series of computations with the phosphorus decay model was performed to distribute phosphorus concentrations at each point in the Charles among the point and nonpoint source contributors to those concentrations. These distributions are presented in Table 6-1 and compared with the 1973 DWPC phosphorus data for Q_{CRV} = 124 cfs. In the nomenclature of this table, C_o and C_t are the phosphorus concentrations at the upstream and downstream ends, respectively, of each water quality section.

The computed upstream phosphorus concentrations, due almost entirely to the estimated point source loadings, are lower by one-half than the DWPC observed concentrations, while the computed downstream concentrations agree closely with observations. If the estimates for upstream flows were too low, however, their correction would result in computed phosphorus concentrations even lower than those in Table 6-1. It seems more likely then, in spite of the obvious flow uncertainties, that the phosphorus loadings reported by DWPC for the upstream treatment plants have been greatly underestimated. Using more typical effluent values

706045

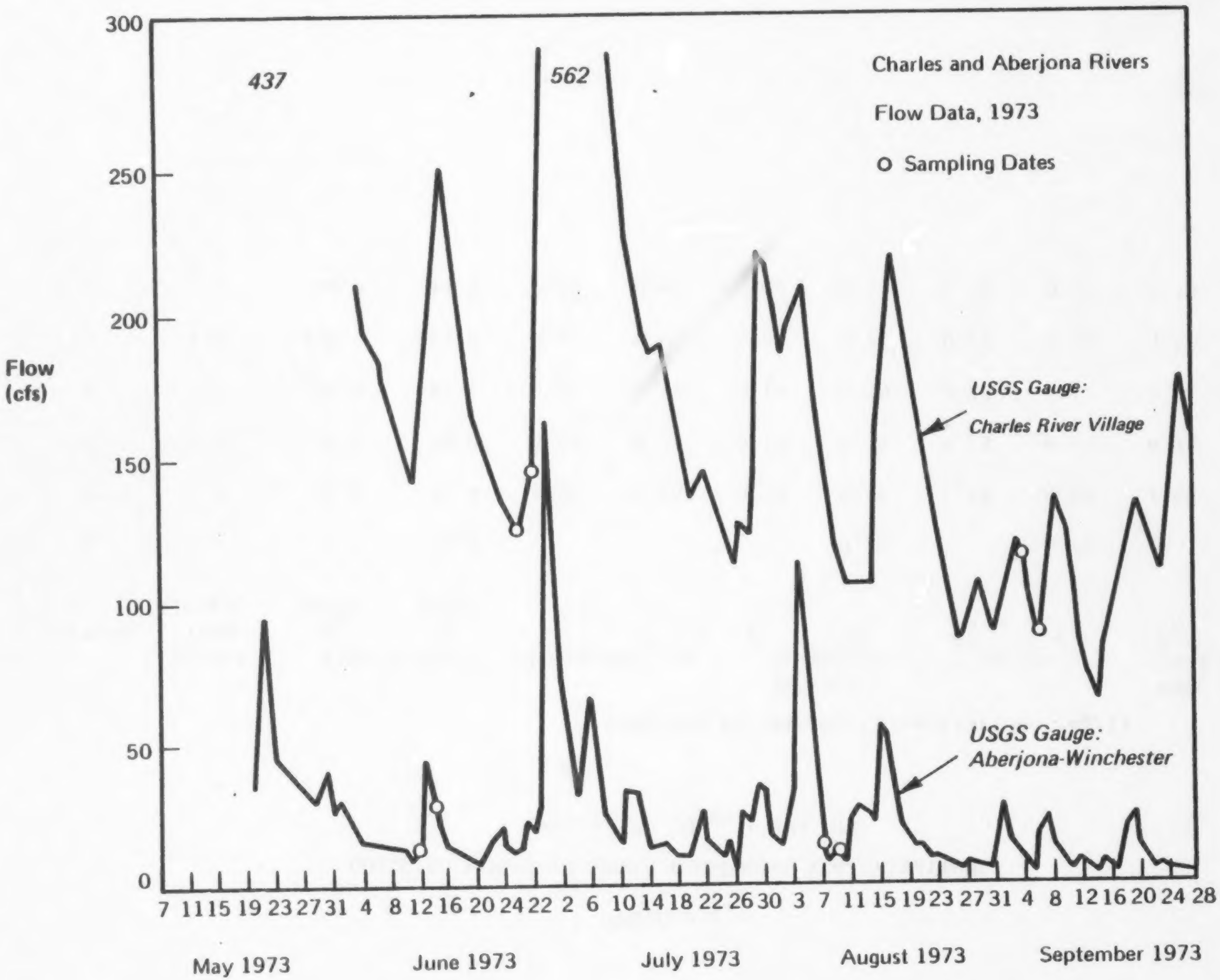

Figure 6-2 Charles and Aberjona River Flow Data, 1973

TABLE 6-1

COMPUTED VERSUS OBSERVED PHOSPHORUS CONCENTRATIONS

June, 1973: $Q_{CRV} = 124$ cfs

				Computed Phosphorus Concentrations (mg/l)							
		Flow Rates		Point Sources		NPS and Stormwater		Totals		DWPC June 1973 Data	
Section	Travel Time (days)	Q_o (cfs)	Q_t (cfs)	C_o	C_t	C_o	C_t	C_o	C_t	C_o	C_t
1	5.6	-	4.9	-	-	-	0.70	-	0.70	-	0.17
2	4.7	11.3	26.0	1.38	0.38	0.30	0.18	1.68	0.56	3.55	0.75
3	3.7	39.6	60.0	0.61	0.28	0.12	0.24	0.73	0.52	0.93	0.58
4	3.2	75.3	97.1	0.31	0.17	0.19	0.30	0.50	0.47	0.44	0.45
5	3.3	106.5	192.6	0.16	0.09	0.28	0.24	0.44	0.33	0.50	0.36
6	7.0	86.4	114.4	0.09	0.03	0.24	0.33	0.33	0.36	0.39	0.27

(see Section 5), computed phosphorus concentrations would agree more closely with those observed the length of the river.

It should further be noted that these model calibrations were at a Charles River Village flow rate of 124 cfs and that all pollution loadings were based upon estimated annual averages. For the examination of point source loadings, stormwater runoff, combined sewer overflows and bypasses, all of which remain relatively independent of stream flow, this presents no great difficulty to estimating water quality under other, typically much lower, flow conditions. Nonpoint source loadings, however, are quite another matter. These will be very much a function of streamflow, as the phosphorus fluxes in Figure 6-1 clearly indicate. The limited evidence in the Charles (see Figure D-1, Appendix D) indicates that the concentrations attributable to nonpoint source loadings may be more nearly constant than are the loadings themselves. Since it was not possible to develop a very simple relationship between streamflow and nonpoint source loadings, the approach adopted in this analysis was to assume nonpoint sources to be reduced to insignificance when considering very low or drought regime flow conditions. Water quality in the Boston area is now, and for the foreseeable future will continue to be, dominated by point source discharges, combined sewer overflow and urban stormwater runoff under these conditions.

6.3 Algal Biomass Model

Algal biomass was expressed, in the recommended water quality criteria, in terms of chlorophyll-a. The expression adopted in this analysis to relate chlorophyll-a to available nitrogen and phosphorus was the Monad formulation developed by Harris (1976) for the Potomac River estuary. This is a stoichiometric, rather than a kinetic, model. For any given combination of total nitrogen and phosphorus concentrations, the model projects the maximum algal biomass, as chlorophyll-a, that would subsequently be able to develop. The model thus can deal with either nitrogen-limited or phosphorus-limited conditions or any nutrient combination in between. Based upon the primary source of pollution of a water quality section and the nitrogen/phosphorus ratio in that source, an allowable or limiting phosphorus concentration can be established for the section, whether phosphorus is actually the algal growth limiting nutrient or simply acting as a surrogate for the nutrient combination that is. Where urban stormwater, for example, is the primary pollution source, the limiting phosphorus concentration would be 0.11 mg/l. For combined sewer overflows, the limiting phosphorus concentration would be 0.067 mg/l and for nonpoint sources would be 0.038 mg/l. During this analysis, 0.05 mg/l was used generally as the water quality objective for phosphorus. More detailed planning, with more definitive data, would consider the distribution of pollution sources more carefully in establishing allowable nutrient loadings for individual water quality sections.

6.4 Simplified Charles River Basin Model

The Charles River Basin is the one Boston area location for which a detailed mechanistic chemical and biological population dynamics model exists. This model was originally developed to simulate spatial and temporal changes in algal and bacterial populations and other water quality parameters over a long period of hydrologic and meteorological record and in response to a number of alternative water quality management strategies keyed to instream treatment of the river to recover from upstream pollution sources (Process Research, Inc. 1975, 1976). One of the requirements of this analysis, however, was to be able to generalize the methods developed and employed to other conditions and areas of the country. By this criterion, the original Charles Basin Model was considered to be unnecessarily complex. By retaining the geometric properties of the original model and combining these with the upper Charles first-order decay model, a much simplified and more readily generalizable model of the basin was created. The simplified model was designed to predict phosphorus and coliform bacteria concentrations under specific conditions of flow and pollution loadings. It allowed the consideration of stratification or destratification of the Basin by alterations of coliform die-off coefficients and available fresh water flow volumes. The simplified model was calibrated against available water quality data, as well as against projections from the original model under flow conditions for which water quality data were unavailable.

6.5 Boston Harbor Coliform Model

The Boston Harbor coliform model used in this analysis was a purely empirical model. It follows the logic of existing steady-state models of the Harbor (Hydroscience, Inc. 1971; Process Research, Inc. 1974) in that (1) the time-averaged pollutant concentration of any point resulting from a pollutant discharge source at that or any other point is directly proportional to the magnitude of that source and (2) the total concentration at any point is the simple summation of all concentrations at that point resulting from all pollution discharges at that and all other points. The mean bacterial concentration at any location in the Harbor, then, was represented by a linear combination of terms, one term for each of the bacterial sources in the harbor, each term consisting of a bacterial loading rate multiplied by a phenomenological coefficient. Each coefficient describes completely the influence of a pollution source in one specific location upon the concentration of the pollutant in another specific location. The complete harbor model is represented by a matrix of these coefficients, referred to as a unit transfer matrix. The original Hydroscience transfer matrix was developed from theoretical solutions of hydrodynamic, dispersion and bacterial decay equations for each of a large number of geometrically described segments of Boston Harbor. It is argued here that the theoretical, or mechanistic, derivation of coefficient values for this transfer matrix is not only unnecessary where adequate data are available, but tends to obscure the requirements for calibration data. The empirical approach, consciously ignoring any mechanistic interpretations, arrives at the same general model form, but the necessary data required for its calibration are clearly delineated and the inadequacies in the available data are clearly exposed. In the case of the simple 5-section model of Boston Harbor used in this analysis, five different groups of pollution loadings data (or in this case, estimates), along with the five respective pollutant concentrations for a given section, are required to determine the five transfer coefficients for the section. In view of a consistent reluctance of water quality planners to collect the data appropriate to the problems they are planning to solve, any analytical approach that demands correction of this data problem has intrinsic merit.

7. ALTERNATIVE POLLUTION CONTROL TECHNOLOGIES

The list of alternative pollution control technologies examined for their applicabilities in the Boston metropolitan area was by no means intended to be exhaustive; rather, it was intended to be simply representative of the array of tools available to a water quality management planner, in contrast to those few and largely inappropriate technologies to which the EMMA study was limited. Conventional, and less conventional, structural alternatives as well as examples of nonstructural alternatives were examined in this analysis. Technologies are grouped below according to their application by pollution source category.

7.1 Continuous Point Source Discharges

Pollution control technologies for continuous point source discharges are conventially categorized as primary, secondary, tertiary, or advanced waste treatment (AWT), in generally ascending order of pollutant removal efficiencies. Effluent characteristics common for these control technologies are tabulated in Section 5 of this report.

Primary Treatment

Primary treatment, represented by the present Deer and Nut Island treatment plants, is a series of simple physical processes: screening and grit removal for the large and very dense materials suspended in sewage, and prolonged sedimentation (typically 2 hours) to allow for the gravitational settling of smaller and less dense particulates. Overall removals of BOD and suspended solids in primary treatment is 30 to 40%. Nutrient (nitrogen and phosphorus) removal is typically less than 5%. Effluent from the primary sedimentation tanks is usually disinfected to kill pathogenic organisms before discharge to receiving waters. In the Boston area, chlorination for 15 minutes is the routine disinfection process employed. A number of questions about this practice can be raised. First, because of the high remaining solids concentrations in primary effluents, viruses and some other pathogens are believed to be well shielded from the chlorine, while the coliform organisms later counted upon to indicate their presence in receiving waters are destroyed. Second, the chlorination of organics present in primary effluents results in the production and discharge of large concentrations of a number of now well-known carcinogenic compounds. The impacts of these chlorinated compounds on fish, wildlife and receiving-water ecologies have yet to be clearly demonstrated, although there are increasing observations of tumors in fish and shellfish from waters receiving chlorinated effluents. Finally, chlorine itself is lethal to fish at 1/100th the concentrations typically employed for disinfection.

The solid materials removed in the primary process are collected in an aqueous sludge. This sludge is dewatered and anaerobically digested (to reduce putrescence) or incinerated or land-filled or sometimes all four. Deer and Nut Island sludges are presently discharged to Boston Harbor with the Deer Island effluent.

Secondary Treatment

Secondary treatment is simply the addition of a biological oxidation step, and another (secondary) sedimentation step, to the primary sedimentation process described above. The two principal secondary processes, activated sludge and trickling filter, and their many design permutations all function to degrade organic materials by accelerated micro-biological action. Additional suspended solids removals are also achieved through absorption of solids by clumps of microbial organisms and their subsequent settling in the secondary sedimentation step. Overall removals of BOD and suspended solids through a well functioning secondary treatment system is typically expected to be 80 to 90%. Because of the active biological oxidation and increased solids removal in the secondary step, the removal of bacteria and presumably pathogenic organisms increases to 99% beyond that achieved by primary treatment alone. Removal of metals and other contaminants also increases with increasing solids removals. Overall nutrient removals increase to about 15% for nitrogen and 50% for phosphorus. Nitrogen undergoes progressive oxidation between the primary and secondary treatment stages from organically bound nitrogen to ammonia to nitrite and nitrate. Sludge quantities double between the primary and secondary treatment stages.

Tertiary or Advanced Waste Treatment (AWT)

Advanced waste treatment (AWT) is typically defined as anything additional that is done beyond the conventional secondary treatment processes. AWT can mean additional nitrogen removal by, first, nitrification (complete oxidation of all nitrogen to the nitrate form) and then denitrification (anaerobic reduction of nitrate to nitrogen gas, which escapes to the atmosphere). AWT can mean additional phosphorus removal by precipitation with lime or alum, with or without a final filtration step. AWT may include additional removal of organic compounds, biodegradable or refractory, by adsorption on columns of activated carbon; it may include reduction of dissolved solids by acid-base ion exchange. AWT may include any combination of any or all of the above processes and sometimes does. In the Boston area, AWT seems generally to mean conventional or expanded secondary treatment, coupled with phosphorus precipitation and filtration (Leu and Chervincky 1977).

Land Application Systems

Land application or treatment are terms used to describe the process of applying domestic and/or industrial wastewaters to soils to renovate water, recycle nutrients, dispose of waste products or replenish ground waters. Land application systems fall generally into one of three categories: irrigation, infiltration-percolation or overland flow. These are described in some detail in Appendix H.

Land application systems, where possible, can offer a number of advantages over the conventional primary, secondary, tertiary or advanced process trains. Effluent quality is equivalent to or, in terms of some parameters, superior to that from the quite complex AWT systems. Land treatment systems can be designed to distribute effluents selectively between surface waters and groundwater replenishment, depending upon local water resource requirements. Pretreatment requirements for land application are minimal: winter storage and oxidation lagooning in the northern and northeastern United States. Sludge disposal difficulties are minimal with land systems because of the very slow rates of accumulation. The EPA construction grants program allows the federal contribution of 75% of the acquisition costs of land used for treatment but not for the land on which the AWT plant is built. The financial implication not usually called to the attention of local communities is that open space acreage can be acquired in large blocks and preserved for future use with this substantial federal subsidy.

Nonstructural Alternatives

A number of nonstructural alternatives are available for reducing both the wastewater flows and the pollutants in those flows to any point source treatment facility. The elimination of excess infiltration and inflow (I/I) to sewage collection systems can reduce by varying amounts the wastewater flows requiring treatment. The implementation of available water-conserving devices and policies, as has been sometimes painfully demonstrated in northern California during the past several years, can result in dramatic reductions in both water use and wastewater production. By ignoring any possibilities for I/I control and forecasting an increase in future household water use, the EMMA study ended up planning around per capita wastewater flows for the year 2000 that were twice those measured in the Boston area today. Prohibition of household garbage grinders can reduce organics and solids loadings to treatment plants by 20% or more.

The ultimate reduction in municipal point source pollutant discharges, of course, lies in the avoidance of becoming a point source in the first place. This can be accomplished by adequately designed and maintained on-site disposal systems rather than the extensive sewerage recommended by state pollution control authorities and the engineering consulting profession.

7.2 Intermittent Point Source Discharges: Stormwater Runoff, Bypasses and Combined Sewer Overflows

The discharges to receiving waters of untreated urban stormwater, raw sewage bypasses and combined sewer overflows constitute (1) the most serious of the pollution problems in the urban waterways of the United States (Boston included) today and (2) the very problems receiving the least and last attention of the EPA construction grants program, as well as, perhaps because of, the water quality management planning process generally. While the existence of these problems has not gone unnoticed, sources of financing for the historically astronomical costs estimated for their correction (as much as $300 billion was estimated as the national need by the National Commission on Water Quality as recently as 1975) had been simply unimaginable. These cost estimates had been astronomical because they had been based upon an inability to distinguish between traditional concepts of flood control and those more appropriate for pollution control.

It was at one time, and in Boston still is, common to design in terms of the volumetric rates of runoff or overflows to be contained, stored, pumped and/or treated during the wet weather event, ignoring the observations that the pollutants overflow usually at quite different rates than do the volumes (first flush phenomena, etc.). In addition this volumetrically, or hydrologically, based design approach ignored completely the opportunities for preclusion of pollutants from those volumes before the event. Along with this limited engineering concentration on hydrology came the traditional hydrologic concept of the "design storm"; that is, facilities would be designed for a certain hydraulic performance during one particular, quite arbitrarily selected, storm event having a specific statistical recurrence frequency. Performance or functioning of the facilities during the infinite number of storm events with different intensities, different durations and different recurrence intervals, is ignored by the "design storm" approach. Any study, analysis, planning or design of stormwater-related pollution control strategies that appears based upon a "design storm" concept can be argued as a misunderstanding of the issues of cost-effective pollution control, as well as water quality management.

Within recent years, it has become increasingly common to consider stormwater-related problems in terms of long-term (20 years or more) meteorological records, where performance of alternative control strategies can be examined across the broad spectrum of rainfall and runoff characteristics actually encountered. This latter approach was adopted throughout the analysis in this case study.

Storage and Treatment

Construction of adequate treatment plant capacity to process all or most of the runoff and overflows as they occur is extremely expensive, and this additional treatment plant will sit idle during dry weather, which is most of the time. Addition of storage capacity, however, will allow a smaller treatment plant, operating more nearly continuously, to process the runoff and/or overflows at a slower rate. The storage capacity functions as a flow equalizer in this application, with runoff or overflows in excess of the combined storage/treatment capacity discharging to receiving waters untreated. The design of such a system involves tradeoffs among the costs of storage, costs of treatment and fractions of pollutants captured or removed. An instructive analysis of the optimal (least cost) combination of storage and treatment in this application is presented in Appendix F. A principal conclusion of this analysis is that, for any level of pollutant removal above about 10 or 20%, much higher treatment levels (secondary or AWT) would be less costly, in dollars per pound of pollutant removed, than the primary treatment usually contemplated.

Detention/Chlorination

Detention and chlorination of combined sewer overflows is the Boston area concept of storage/treatment. It offers the very least pollutant removal of any of the storage/treatment combinations, 15 minutes of detention and chlorination during "design storm" conditions. The MDC's Cottage Farm Detention/Chlorination Facility was constructed in 1970-71 with the aid of an EPA demonstration grant. In spite of available evidence to the contrary, DWPC predicted in 1971 that this facility, in conjunction with the construction of the new Warren Avenue dam, would raise the quality of water in the Charles River Basin to C condition (Jobin and Ferullo 1971). Water quality in the Charles Basin in 1971 was in condition U. Water quality in the Charles Basin in 1977, after six years of operation of the Cottage Farm facility, is in condition U. Water quality in the Charles Basin in 1978, after completion of the Warren Avenue dam, will almost certainly continue to be in condition U.

Despite the absence of any of the predicted water quality improvements resulting from the detention/chlorination experiment, the concept is being proliferated throughout the Boston area by the MDC and is recommended by the EMMA study. The MDC will complete construction in 1978 of a new detention/chlorination facility located adjacent to the new Warren Avenue dam. The EMMA study proposes $270 million to $300 million for construction of additional detention/chlorination facilities throughout the Boston area.

In-Line Storage

As practiced in a number of United States cities, for example, in Seattle and Minneapolis-St. Paul, the available in-line storage in combined sewer systems is maximized by closing off overflow or bypass points until there are clear and present flooding dangers. In this way, necessary storage, for the small to medium, high frequency of recurrence storm events, is provided within the existing sewer system. In these cases, adequate capacity for subsequent treatment is available at existing treatment facilities. Such in-line storage systems are typically automated, and the Seattle system provides on-line real-time computerized control of storage locations, flow routing and selective diversion of overflows to least sensitive water quality sections.

Automated Sewer Flushing

The late Thomas Camp, founder of the Boston firm of consulting engineers, Camp, Dresser and McKee, Inc., claimed many decades ago that, on the average, 30% of the pollutants in combined sewer systems overflow during 3% of the time. More recent data from many places in the country have verified that Camp's early estimate was remarkably accurate. Typically 10 to 50% of the pollutants entering combined collection systems deposit and accumulate within the oversized pipes in those systems. During the small fraction of the time that stormwater enters and floods the combined sewers, these accumulated pollutants are resuspended and washed out through the overflows and bypasses directly to the nearest receiving waters. The concept of actively and periodically flushing combined sewer systems was based upon a recognition that the wet weather polluting characteristics of these systems was a direct consequence of their dry weather deposition characteristics and that the dry weather deposition could be relatively easily modified and/or controlled by flushing the systems with sufficient frequency that the stormwater would enter pipes free of accumulated deposits. The systems' overflowing pollutants would be reduced, on the average, from 30% to less than 3%.

The original Boston Main Drainage System, constructed in the late nineteenth century and largely still in operation today, was designed to be periodically flushed, precisely to prevent the accumulation of deposited pollutants during dry weather flows (Clarke 1885). More recently proposed flushing systems have relied upon the automation technologies developed for in-line storage and flow routing systems and the enormous advances in automated control capabilities presented by the explosion in micro-processor and mini-computer technology (Process Research, Inc. 1974; Smith, Harrington and Flaherty 1977). Conceptually, a sewer flushing system today would consist of a network of automated control valves operated to temporarily store in-line and then rapidly pulse controlled volumes of sewage through the combined sewers to the treatment facility at sufficient flow velocities to prevent deposition. While this dry weather operating mode is designed to upgrade the quality of subsequent wet weather overflows, the same control network would be operated during wet weather to maximize the available in-line storage, so that the quantities of overflows would be reduced as well.

Street Cleaning

Similar to combined sewer overflows, the pollution potential of urban stormwater runoff is a direct consequence of the materials allowed to accumulate on streets and other impervious urban areas during the antecedent dry weather periods. As with the flushing of combined sewer systems, intensive street cleaning operations are a pollution preventative alternative to the need for processing massive volumes of stormwater. Street cleaning operations designed for water pollution control, however, would undoubtedly be different from those presently designed for aesthetic purposes. Of far greater concern would be the very fine materials (40 microns and smaller) that either escape or are increased by conventional mechanical sweepers. Street cleaning for water pollution control will probably dictate vacuum-type cleaners, although intensive street washing may well be an acceptable or even preferable alternative in combined sewered areas. Since 90% of the pollutants found on street surfaces are found within 12 inches of the curbs, parked automobiles clearly present the major difficulty for any effective street cleaning operation. Vacuum equipment could be developed to clean around and under parked vehicles, but there has to date been no incentive for equipment manufacturers to do so (Horton 1977).

While the sparse available data indicate that the majority of water polluting materials seems to accumulate in street gutters, and other accessible locations such as parking lots, any casual visit to the Beacon Hill area of Boston would provide immediate and convincing evidence of a correlation between sidewalks, dogs and polluting materials. Urban surfaces other than street gutters ought also not be overlooked.

7.3 Nonpoint Sources

Control alternatives for nonpoint source pollution are typically nonstructural in nature. They include land use policies to maintain protective vegetation buffers adjacent to stream banks and roadways and to minimize impervious areas generally. They include regulations designed to preclude landfill locations and construction activities from flood plains. They include regulation of fertilizer and agricultural chemicals applications and stipulations of erosion control practices. In the suburban areas of metropolitan Boston, failing septic tanks are noted often as nonpoint source pollution sources, but convincing documentation of this problem is scant. Local community acquisition and maintenance of existing and new on-site disposal systems may be an effective response to the failing septic tank problem and a less-costly alternative to sewering. Greater reliance on sand than chemicals for winter road de-icing, and protective covering of road salt stockpiles, can reduce the salt contamination of both surface and ground waters.

8. ALTERNATIVE CASE STUDY CONTROL STRATEGIES

8.1 Introduction

Three fundamental control strategy categories were examined in this case study. The first, Category I, considered the maximum use of existing facilities, upgraded and rehabilitated as necessary to minimize pollutant discharges from the present MSD system. Facilities were those necessary for the present MSD service area and for the EMMA projected year 2000 service area. Within this alternative also were examined a number of urban stormwater and combined sewer overflow control options. The second, Category II, was the EMMA recommended plan, with all the EMMA planning criteria and engineering assumptions. The third, Category III, considered a series of possible modifications and alterations to the EMMA plan facilities.

Federal Study Team Alternatives - Category I

The baseline criteria for these alternatives limited the MSD service area, per capita wastewater flows, infiltration and industrial allowances, and assumed that sewers would be rehabilitated to reduce inflows in accordance with proposed EPA cost-effectiveness guidelines. All treatment was located at Deer Island and Nut Island with effluents discharged at present locations. The alternatives within Category I were as follows.

A. Upgrade and rehabilitate the existing MSD facilities. Serve existing sewered areas only.

B. Expand existing MSD facilities to provide adequate primary treatment to serve the same flows as in IA above.

C. Expand existing MSD facilities and expand service area to serve year 2000 population, as projected by EMMA, in the existing member communities, but with limited flow allowances as above.

D. Add combinations of five different approaches to the control of intermittent wet weather pollution from separate storm and combined sewered areas tributary to Deer Island.

1. Retain combined sewer overflows with expanded primary treatment capacity at Deer Island.
2. Automate dry weather flushing of combined sewer deposits, with wet weather in-line storage.
3. Provide storage and separate treatment of urban stormwater.
4. Provide street cleaning for urban runoff source control.
5. Provide EMMA-recommended detention/chlorination facilities for combined sewer overflows at EMMA-estimated costs of $270 million.

(All Alternative ID options included 100 mgd additional wet weather treatment capacity at Deer Island.)

E. Add secondary treatment to Deer and Nut Island facilities.

EMMA Recommended Plan - Category II

Alternative A, under this category, was the EMMA recommended plan for upgraded and expanded MSD facilities according to the EMMA projected year 2000 service areas, populations, wastewater flows and characteristics. It included two satellite AWT facilities discharging to the Charles and Neponset Rivers, secondary treatment plants at Deer and Nut Islands discharging to Boston Harbor, and $270 million for chlorination and detention of combined sewer overflows prior to their discharge to inland rivers, estuaries and Boston Harbor. Alternative B added some modifications and rehabilitations suggested by Kennedy Engineers for the Deer and Nut Island treatment plants that were not considered in the EMMA plan as recommended.

Alternatives to the EMMA Recommended Plan - Category III

The water quality impacts of a series of alternative facilities were examined in this category. The year 2000 service areas, populations, wastewater flows and characteristics for each remained the same as those for the EMMA recommended plan.

A. EMMA without satellite plants, with consolidated treatment at Nut Island; Deer Island and Nut Island secondary effluents discharged to Boston Harbor.

B. EMMA with two satellite secondary plants; effluents conveyed to Boston Harbor.

C. EMMA with two satellite secondary plants; effluents discharged to rivers adjacent to plants.

D. EMMA with two satellite lagoon treatment plants and land disposal of effluents.

E. EMMA with one satellite secondary plant; effluent conveyed to Boston Harbor.

F. EMMA with one satellite secondary plant discharging to the Neponset River.

G. EMMA with one satellite lagoon treatment plant and land disposal of effluent.

H. EMMA with one satellite AWT plant discharging to Neponset River.

J. EMMA without satellite plants; also without secondary treatment; Deer and Nut Islands discharging primary effluents to deep ocean water.

K. EMMA without satellite plants; without secondary treatment; discharging primary effluents to Boston Harbor.

For the Category III alternatives, the water quality impact of eliminating the present diversion of flow from the Charles to the Neponset River through Mother Brook was also examined.

8.2 Category I Alternatives: Baseline Conditions

These baseline alternatives examined the pollution loading and water quality impacts of repairing and upgrading the existing MSD system and correcting existing infiltration and inflow problems. The baseline wastewater flows resulting from the thus repaired and corrected sewer systems were assumed to be more nearly in conformance with recently proposed EPA cost-effectiveness guidelines (Federal Register, 4 February 1977, p. 6841). Residential and commercial flows were estimated to be 85 gpcd, with an infiltration allowance for rehabilitated sewer systems of 30 gpcd. Industrial flows remained the same as those projected by the EMMA study. By comparison, the average dry weather flows to Deer Island were estimated by the EMMA study at 235 gpcd in 1970 and were projected to increase by the year 2000 to 274 gpcd. There is evidence that the EMMA estimated wastewater flows are greatly overstated. For example, the EMMA study estimated that the average dry weather flow from the Dorchester area of Boston was 22.3 mgd in 1970. Flow measurements in the Dorchester sewer system during 1974 indicated the average dry weather flow to be 11 mgd, with an average daily peak flow of 14 mgd (Process Research, Inc. 1974); these measurements are shown in Figure 8-1. With the alternative baseline flows assumed above, the estimated 1970 average Dorchester flow would be 15.9 mgd, still 50% greater than the flows measured in 1974.

Since the design capacity of the Dorchester interceptor is 25.9 mgd, the excess wet weather flow capacity in a rehabilitated system would be 10 mgd, or 63% of the average dry weather flow. This 10 mgd of excess carrying capacity, distributed over the 1256 acres* of combined sewer service area would be 0.29 inches/day. Similarly, the resulting excess inline storage that would be available during wet weather was calculated to be 0.08 inch. The present excess wet weather carrying capacity in the Dorchester Interceptor is essentially zero because of accumulated long-term deposits throughout much of its length. The reduction in the volumes of combined sewer overflows resulting from cleaning, repairs and rehabilitation can therefore be calculated directly, from Equation (2) in Appendix F, to be 32%. Pollutant overflows, moreover, would be reduced to a somewhat greater extent if a first flush phenomenon were assumed. More of the first flush during small storm events would be allowed by the additional interceptor carrying capacity to reach the treatment plant instead of overflowing. Equation (3) in Appendix F would calculate pollutant overflow reductions from the combined sewers

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*Includes 305 acres of separate sanitary service area with roof drain and other connections to combined sewers.

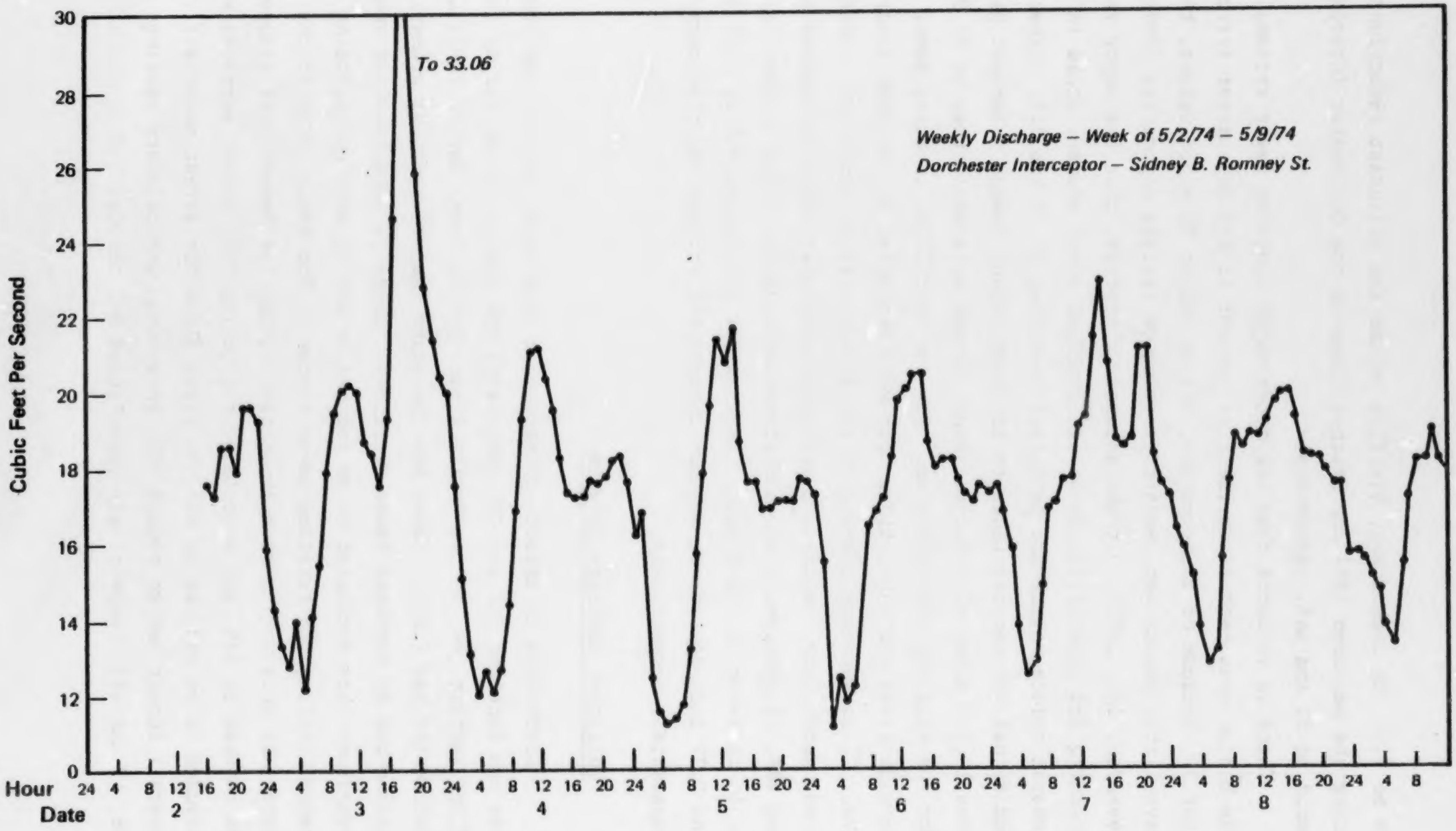


Figure 8-1 Dry Weather Flow in Dorchester Interceptor, 1974

to be 51%. By comparison, overflow volume and pollutant reductions using the measured 1974 dry weather flows in the Dorchester Interceptor would be 52 and 68%, respectively.

There is evidence that the other major combined sewer systems in the Boston area behave similarly at present to the Dorchester system; that is, because of infiltration, inflow and/or flow occlusions, they have little excess wet weather carrying or storage capacities (Process Research, Inc. 1972). It was assumed, therefore, that the major repair, cleaning and rehabilitation of all combined sewer systems would in general reduce volume and pollutant overflows by 32 and 51%, respectively. Additional wet weather flows to the Deer Island sewage treatment plant from 10,747 acres of combined sewer service area would then be 84.9 mgd for the existing (1970) system. For the year 2000, combined sewer service areas and populations both were projected by the EMMA Study (Vol. 7) to decrease overall in the Boston area by about 10%. Under these conditions, volume and pollutant overflows would be reduced by 41 and 58%, respectively, and additional wet weather flows to Deer Island would increase to 100.3 mgd. These values are equivalent to 0.09 inch and 0.37 inch/day of wet weather interceptor storage and flow carrying capacities, respectively.

Pollutant Loadings Impacts

Alternative IA impacts primarily on five water quality sections: the two sections (C7 and C8) comprising the Charles River Basin; the final section (M4) on the Mystic River; Boston Inner Harbor (BH1) and Dorchester Bay (BH2). These are the water quality sections primarily influenced by combined sewer overflows. Loadings from combined sewer overflows were estimated to be reduced by 50% or more by upgrading and rehabilitating the existing sewer systems. For these calculations, materials originating from deposition within the sewers were assumed to be reduced by 58%, and materials originating from street surfaces were assumed to be reduced by 41% (no first flush for street materials). The overall impact was to reduce BOD, phosphorus and coliform loadings by 28, 19 and 48%, respectively (see Tables 8-1 through 8-3).

TABLE 8-1

BOD LOADINGS (lb/day)
ALTERNATIVE: IA, B, C

Basin Section	Urban Stormwater		Combined Sewer Overflows		Non-point Source			Point Source Discharges		Total Loadings		
	1970	IABC	1970	IABC	1970	IAB	C	1970	IABC	1970	IAC	C
CHARLES												
C1	312	405			222	220	200	1	-	535	625	605
C2	151	193			216	206	182	670	157	1037	556	532
C3	900	1359			933	1006	909	1900	375	3733	2740	2643
C4	1486	2397			1335	1258	1084	1126	164	3947	3819	3645
C5	1106	1385			251	246	155	-	-	1357	1631	1540
C6	3953	4604			750	821	443	-	-	4703	5425	5047
C7	1165	1129	222	30	121	120	120	-	-	2086	1333	1333
			578	54								
C8	1801	1968	831	446	204	215	215	-	-	5491	3476	3476
			2655	847								
MYSTIC												
M1	1215	1525			345	360	201	-	-	1560	1885	1726
M2	260	257			32	34	27	-	-	292	291	284
M3	858	894			110	92	87	-	-	968	986	981
M4	1301	1184	192	92	170	177	177	-	-	2282	1655	1655
			619	202								
NEPONSET												
N1	1187	1677			760	676	517	58	37	2005	2390	2231
N2	1658	2284			787	758	538	217	217	2662	3259	3039
N3	1161	1117			146	146	146	(1200)	(1200)	2507	2463	2463
BOSTON HARBOR												
BH1	600	638	962	482	150	210	210	(6000)	(4380)	9415	6379	6379
			1703	669								
BH2	513	543	324	216	142	96	96	(1400)	(1400)	3637	2776	2776
			1258	521								
BH3	302	306	-	-	54	53	53	*	*	356	359	369
BH4	148	100	-	-	30	63	63	†	†	178	163	163

IA	*Nut Island STP	120,000
	†Deer Island STP	219,000
IB	*	117,000
	†	215,000
IC	*	149,000
	†	235,000

TABLE 8-2

P LOADINGS (lb/day)

ALTERNATIVE: IA, B, C

Basin Section	Urban Stormwater		Combined Sewer Overflows		Non-point Source			Point Source Discharges			Total Loadings		
	1970	IABC	1970	IABC	1970	IAB	C	1970	IAB	C	1970	IAC	C
CHARLES													
C1	17	22			7	6	6	-	-	-	24	28	28
C2	8	10			9	8	8	84	22	31	101	40	49
C3	48	72			25	30	29	78	13	75	151	115	176
C4	80	128			38	33	32	34	8	34	152	169	193
C5	54	69			6	4	3	-		-	60	73	72
C6	193	233			18	13	11				211	246	244
C7	60	58	12	3	1	1	1				84	64	64
			11	2									
C8	91	92	44	23	2	2	2				188	134	134
			51	17									
MYSTIC													
M1	68	84			12	9	7				30	93	91
M2	15	16			1	1	-				16	17	16
M3	48	51			3	2	2				51	53	53
M4	72	69	11	6	6	6	6				101	85	85
			12	4									
NEPONSET													
N1	68	94			28	20	19	8	5	5	104	119	118
N2	95	125			26	21	19	4	4	4	125	150	148
N3	62	63			3	2	2	(36)	(22)	(44)	137	87	109
BOSTON HARBOR													
BH1	39	44	54	29	2	2	2	(200)	(150)	(150)	328	252	252
			33	14									
BH2	27	29	18	12	2	2	2	(90)	(57)	(72)	161	143	143
			24	10									
BH3	17	18			3	3	3	*		*	20	21	21
BH4	8	6			1	4	4	†		†	9	10	10

IA *Nut Island STP
†Deer Island STP
IB *
†

TABLE 8-3

TOTAL COLIFORM LOADINGS (lb/day): ALTERNATIVES IA, B, C

Basin Section	Urban Stormwater		Combined Sewer Overflows		Non-point Source	Point Source Discharges		Total Loadings	
	1970	IABC	1970	IABC		1970	IABC	1970	IABC
CHARLES									
C1	0.35	0.44						0.35	0.44
C2	0.17	0.21						0.17	0.21
C3	0.97	1.44						0.97	1.44
C4	1.60	2.57						1.60	2.57
C5	1.07	1.38						1.07	1.38
C6	3.86	4.67						3.86	4.67
C7	1.19	1.16	0.24	0.03				4.23	1.45
			2.80	0.26					
C8	1.81	1.84	0.88	0.36				15.52	5.60
			12.83	3.40					
MYSTIC									
M1	1.36	1.67						1.36	1.67
M2	0.30	0.31						0.30	0.31
M3	0.95	1.03						0.95	1.03
M4	1.43	1.38	0.21	0.01				4.64	1.49
			3.00	0.10					
NEPONSET									
N1	1.36	1.88						1.36	1.88
N2	1.89	2.51						1.89	2.51
N3	1.25	1.25				(0.02)	(0.04)	1.27	1.29
BOSTON HARBOR									
BH1	0.78	0.87	1.08	0.45		(0.40)	(0.13)	10.49	4.18
			8.23	2.73					
BH2	0.54	0.59	0.36	0.25		(0.05)	(0.02)	7.03	2.59
			6.08	1.73					
BH3	0.35	0.36				(*)	(*)	0.35	0.36
BH4	0.15	0.11				(†)	(†)	0.15	0.11

IA, B	*Nut Island STP	0.01	0.01
	†Deer Island	10.0	0.03
IC	*	0.02	
	†	0.04	

The baseline conditions for the Charles River Basin and Boston Inner Harbor will be significantly affected in the year 2000 by the presence of the two detention/chlorination facilities and by the different flow estimates for Alternative I. The two detention facilities add the equivalent of 0.05 inch of storage to their tributary areas, in addition to the 0.09 inch resulting from the rehabilitated sewer systems. The Cottage Farm Facility collects overflows from 900 acres of the year 2000 area, shown overflowing to Charles River Section C7 in Tables 5-4 through 5-6, and diverts them downstream to Section C8. The Charles Estuary Facility collects overflows from 1070 acres of the year 2000 area, shown overflowing to Charles River Section C8, and diverts them downstream to the Boston Inner Harbor. The combined sewer service areas with and without these facilities for year 2000 are estimated below:

Combined Sewer Service Areas

Section	Areas without Detention Facilities (acres)	Total with Facilities (acres)	Tributary to Detention Facilities (acres)
C7	1046	226	0
C8	3307	3137	900
BH1	3029	4019	1070

Overflows from the detention facility tributary areas receive some degree of "treatment". The year 2000 pollutant loadings for the above three water quality sections were estimated by the following procedure. First, the year 2000 loadings in Tables 5-4, 5-5 and 5-6 were redistributed among the sections according to the above tributary area redistribution. Second, the reductions of these loadings due to the 0.09 inch and 0.37 inch/day of rehabilitated interceptor storage and transmission capacities were computed. Third, the reductions of the remaining loadings due to the additional storage provided by the overflow detention facilities were computed. Finally, the remaining overflows from detention facility tributary areas that are not completely contained were assumed to be reduced further before overflowing by the following percentages: BOD, 20%; phosphorus, zero and coliform bacteria, 90%. Illustrative of this series of computations are those below for year 2000 BOD loadings from street surfaces and sewer deposits in the combined sewer systems.

BOD Loadings (lb/day) from Combined Sewered Areas

Section	Year 2000 (Table 5-4)	After Redistribution	After System Rehabilitation	Additional Detention	After "Treatment"
C7					
Streets	232	50	30	30	30
Sewers	591	128	54	54	54
C8					
Streets	882	837	494	470	446
Sewers	2409	2285	960	888	847
BH1					
Streets	677	898	530	506	484
Sewers	1347	1787	751	698	669

Similar computations for coliform bacteria loadings for year 2000 Alternatives IA, IB and IC from combined sewer systems are those tabulated below.

Coliform Loadings (lb/day) from Combined Sewered Areas

Section	Year 2000 (Table 5-6)	After Redistribution	After System Rehabilitation	Additional Detention	After "Treatment"
C7	0.25	0.05	0.03	0.03	0.03
	2.86	0.62	0.26	0.26	0.26
C8	0.87	0.83	0.49	0.47	0.36
	11.64	11.04	4.64	4.29	3.40
BH1	0.77	1.02	0.60	0.57	0.45
	6.51	8.64	3.63	3.38	2.73

The Somerville Marginal Conduit and Overflow Pretreatment Facility was assumed to reduce coliforms in the remaining overflows to the Mystic River by 90%. No removals of BOD or phosphorus were assumed for this facility.

Average daily loadings of BOD, phosphorus and total coliforms to each water quality section for year 2000 Alternatives IA, IB and IC are compared with 1970 loadings in Tables 8-1, 8-2 and 8-3.

Water Quality Impacts

Projected coliform concentrations in the Boston Harbor water quality sections are shown in Table 8-4 for 1970 loadings and for the year 2000

TABLE 8-4

AVERAGE BOSTON HARBOR COLIFORM CONCENTRATIONS

(number/100 ml)

Section	1970*	I: A,B,C
BH1 Inner Harbor	1418	544
BH2 Dorchester Bay	909	302
BH3 Quincy Bay	47	39
BH4 President Roads	652	100
BH5 Nantasket Roads	160	46

*1970 loadings, but with tide gates repaired and operating as in 1973.

TABLE 8-5

CHARLES RIVER P CONCENTRATIONS (mg/1)

10-YEAR, 7-DAY, LOW FLOW CONDITIONS

Section	1970		IA, B		IC		IC (AWT Plants only)	
	C_o	C_t	C_o	C_t	C_o	C_t	C_o	C_t
C1	-	1.69	-	1.96	-	1.97	-	-
C2	3.58	1.46	1.10	0.60	1.07	0.73	0.22	0.33
C3	2.71	1.84	0.07	1.05	0.87	0.92	0.82	0.33
C4	2.12	1.83	1.05	1.53	0.95	1.07	0.47	0.22
C5	1.83	1.01	1.53	0.61	1.07	0.64	0.22	0.08
C6	1.01	1.09	0.61	0.77	0.64	0.73	0.02	0.01

Alternatives I: A, B and C. Concentrations in Table 8-4 are those at the sampling points used for calibration of the simplified Boston Harbor Model (see Appendix D). Because of the locations of the major combined sewer overflow points in the Inner Harbor and Dorchester Bay, there are relatively steep coliform concentration gradients across both of these sections (Process Research, Inc. 1974). Concentrations at the furthest inshore point in the Inner Harbor (mouth of the Charles) and in the southernmost area of Dorchester Bay (mouth of the Neponset) can be typically six times those at the sampling points used for model calibration and shown in Table 8-4.

Because there are no available working models for the Mystic and Neponset River systems, concentrations of phosphorus and coliform bacteria in these sections were assumed to be proportional to their loadings, as was the case with the Charles River and Boston Harbor sections. Coliform concentrations in section M4 of the Mystic River will thus be reduced from 10,000/100 ml for 1970 conditions to 3,000/ 100 ml for Alternatives I: A, B and C.

Phosphorus concentrations along the upper Charles River for Alternatives I: A, B and C, were projected for the 10-year, 7-day low flow conditions in the Charles (11.6 cfs at Charles River Village). Phosphorus concentrations at the beginning and end of Charles River sections C1 through C6 for these conditions and for the 1970 loadings are shown on Table 8-5. The acceptable phosphorus level is 0.05 mg/l. Also shown on this table are the phosphorus concentrations resulting from the projected peripheral AWT plants only. The impact of the treatment plants was separated out in this analysis to indicate the upper water quality bound that would exist even in the absence of any additional storm water or nonpoint source loadings during the low flow conditions. Table 8-5 indicates that the peripheral area AWT plant effluents alone discharge enough phosphorus to cause excessive algae blooms throughout the upper Charles during low flow conditions.

Phosphorus concentrations throughout the Charles River Basin (sections C7 and C8) will also be excessive during low flow conditions. The Charles River Basin Model projects phosphorus concentrations of 0.13 and 0.07 mg/l at the ends of sections C7 and C8, respectively, for

Alternatives I: A, B and C. Coliform bacteria concentrations in both sections of the Charles River Basin are projected to be 20,000/100 ml for Alternatives I: A, B and C. These concentrations reflect the elimination of sea water from the Basin and the operation of the two detention/chlorination facilties. Using the 1970 loadings in Table 8-3, prior to the installation of these facilities, coliform concentrations were computed to be 60,000 and 50,000/100 ml for sections C7 and C8, respectively, for a destratified Basin. Adding the salt water back to the bottom 15 feet of the Basin results in coliform concentrations of 60,000 and 40,000/100 ml in sections C7 and C8, respectively, for low flow conditions and year 1970 loadings. These drop to 20,000 and 15,000/100 ml for sections C7 and C8 under Alternatives I: A, B and C, low flow conditions with salt water present.

8.3 Alternative ID Options

Combined Sewer Systems

Figures 8-2 through 8-6 are flow schematics of some representative Boston area combined sewer systems that display the complexities of these existing systems and their interactions with the major MSD facilities: headworks; detention and chlorination stations and pumping capacity at the Deer Island sewage treatment plant. These schematics indicate with diamond shaped symbols the regulator locations in five major combined sewer systems tributary to Deer Island, along with the respective drainage areas to each during dry weather and wet weather. The possible directions in which combined sewage can overflow during wet, and oftentimes dry, weather are shown for each regulator. The Stony Brook system (Figure 8-4) is the largest contributor of combined sewer overflows to the Charles River. The overflow points, however, are scattered throughout the upper sections of this system, and the overflows are primarily to the Stony Brook Conduit and Old Stony Brook Channels, which is the major separate stormwater transmission system for about 9,000 acres of the City of Boston. It becomes particularly difficult to fathom the EMMA overflow facilities in this area, where combined sewer overflows

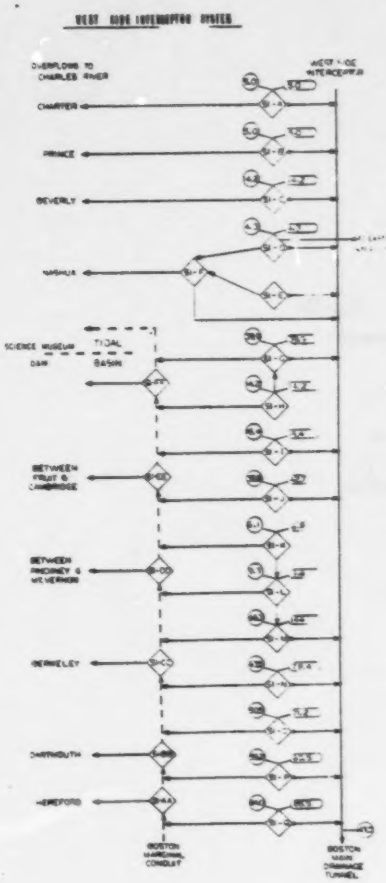

WEST SIDE INTERCEPTOR SYSTEM
OVERFLOWS TO CHARLES RIVER
WEST SIDE INTERCEPTOR
CHARTER
PRINCE
BEVERLY
NASHUA
SCIENCE MUSEUM DAM
TIDAL BASIN
BETWEEN FRUIT & CAMBRIDGE
BETWEEN PINCKNEY & MT. VERNON
BERKELEY
DARTMOUTH
HEREFORD
BOSTON MARGINAL CONDUIT
BOSTON MAIN DRAINAGE TUNNEL

Figure 8-2 West Side Interceptor System

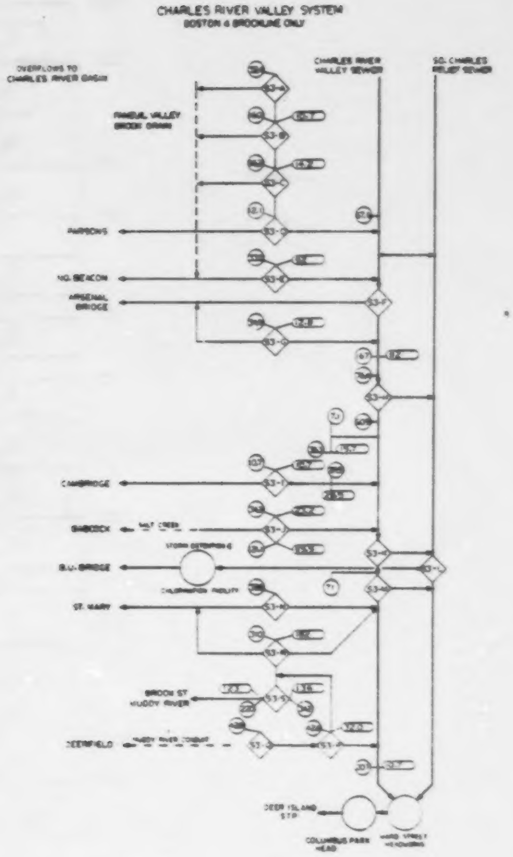
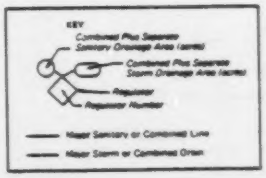

CHARLES RIVER VALLEY SYSTEM
BOSTON & BROOKLINE ONLY
OVERFLOWS TO CHARLES RIVER BASIN
CHARLES RIVER VALLEY SEWER
SO. CHARLES RELIEF SEWER
FANEUIL VALLEY BROOK DRAIN
PARSONS
NO. BEACON
ARSENAL BRIDGE
CAMBRIDGE
BABCOCK
SALT CREEK
STORM DETENTION &
CHLORINATION FACILITY
B.U. BRIDGE
ST. MARY
BROOK ST.
MUDDY RIVER
DEERFIELD
MUDDY RIVER CONDUIT
DEER ISLAND STP
COLUMBUS PARK HEAD
WARD STREET HEADWORKS

Figure 8-3 Charles River Valley System,
Boston and Brookline Only


KEY
Combined Plus Separate Sanitary Drainage Area (acres)
Combined Plus Separate Storm Drainage Area (acres)
Regulator
Regulator Number
Major Sanitary or Combined Line
Major Storm or Combined Drain

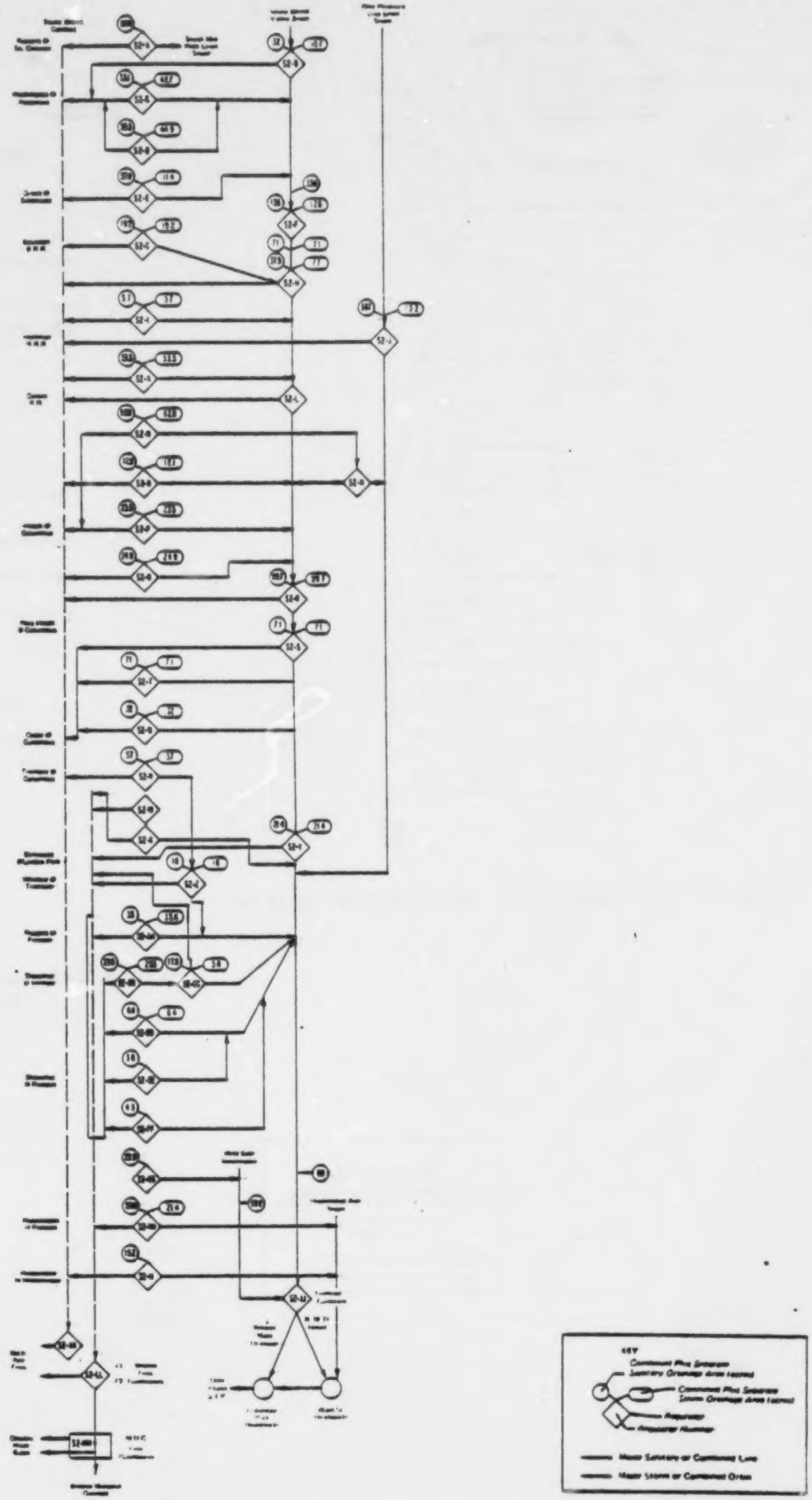

KEY
Combined Plus Separate Sanitary Drainage Area (acres)
Combined Plus Separate Storm Drainage Area (acres)
Regulator
Regulator Number
Major Sanitary or Combined Line
Major Storm or Combined Drain

Figure 8-4 Stony Brook System

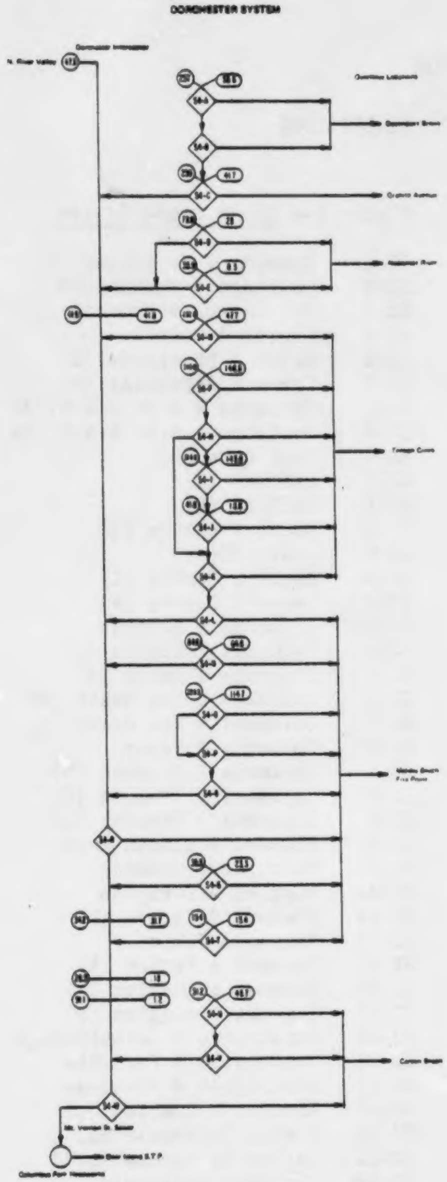

DORCHESTER SYSTEM
Dorchester Interceptor
N. River Valley
Overflow Locations
Mt. Vernon St. Sewer
Deer Island S.T.P.
Columbus Park Headworks

Figure 8-5 Dorchester System

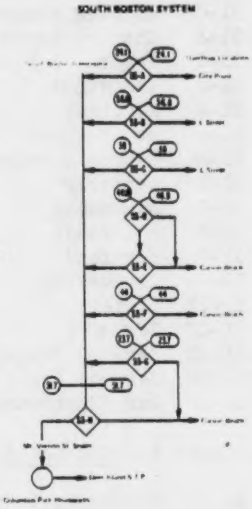
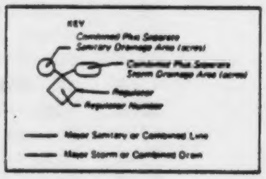

SOUTH BOSTON SYSTEM
Overflow Locations
Mt. Vernon St. Sewer
Deer Island S.T.P.
Columbus Park Headworks

Figure 8-6 South Boston System


KEY
Combined Plus Separate Sanitary Drainage Area (acres)
Combined Plus Separate Storm Drainage Area (acres)
Regulator
Regulator Number
Major Sanitary or Combined Line
Major Storm or Combined Drain

LEGEND FOR

OVERFLOW REGULATOR LOCATIONS

Figure 8-2 West Side Interceptor System

S1-A	Charter
S1-B	Prince
S1-C	Beverley @ Causeway
S1-D	Canal @ Causeway
S1-E	Nashua @ Causeway
S1-F	Nashua
S1-G	Charles River Park (NE)
S1-H	Charles River Park (SW)
S1-I	Fruit
S1-J	Cambridge
S1-K	Pinckney
S1-L	Mt. Vernon
S1-M	Beacon @ Brimmer
S1-N	Berkeley
S1-O	Dartmouth
S1-P	Fairfield
S1-Q	Hereford
S1-AA	Gloucester
S1-BB	Exeter
S1-CC	Berkeley
S1-DD	Between Pinckney & Mt. Vernon
S1-EE	Between Fruit & Cambridge
S1-FF	Dam (Upstream)

Figure 8-3 Charles River Valley System

S3-A	Fairbanks & Washington
S3-B	Faneuil & Newcastle
S3-C	Faneuil & Parsons
S3-D	Birmingham & Parsons
S3-E	North Beacon & Vineland
S3-F	Arsenal & Market
S3-G	Market & Waverly
S3-H	Spurr & Western
S3-I	Bridge & Soldiers Field
S3-J	Babcock & Ashford
S3-K	Penn-Central RR Yards
S3-L	South Charles & B.U. Bridge
S3-M	MS. Tpk. Ext. by B.U. Bridge
S3-N	St. Mary's & Comm. Ave.
S3-O	Kenmore Square
S3-P	Beacon St. & St. Mary's
S3-R	Amory St. - Brookline
S3-S	Brook St. - Brookline

Figure 8-4 Stony Brook System

S2-A	Roberts @ S. Conway
S2-B	McBridge @ Washington
S2-C	St. Joseph @ Woodman
S2-D	Center @ McBride
S2-E	Green @ Brookside (E)
S2-F	Green @ Brookside (W)
S2-G	Boylston @ N.Y. & N.H. RR (W)
S2-H	Boylston @ N.Y. & N.H. RR (E)
S2-I	Paul Gore St.
S2-J	Hoffman (S)
S2-K	Hoffman (N)
S2-L	Amory @ Centre (S)
S2-M	Amory (S)
S2-N	Amory @ Centre (C)
S2-O	Amory @ Centre (W)
S2-P	Columbus @ Ritchie
S2-Q	Columbus @ Centre (E)
S2-R	Columbus @ Heath (W)
S2-S	Columbus @ New Heath (W)
S2-T	Columbus @ New Heath (E)
S2-U	Columbus @ Cedar
S2-V	Columbus @ Tremont (W)
S2-W	Columbus @ Tremont (C)
S2-X	Columbus @ Tremont (SE)
S2-Y	Elmwood @ Linden Park
S2-Z	Whittier @ Tremont
S2-AA	Ruggles @ Forsythe
S2-BB	Shawmut @ Vernon (W)
S2-CC	Vernon @ Cabot
S2-DD	Shawmut @ Vernon (E)
S2-EE	Shawmut @ Ruggles (S)
S2-FF	Shawmut @ Ruggles (N)
S2-GG	Huntington @ Gainsborough
S2-HH	Huntington @ Forsythe
S2-II	Huntington @ Hemenway
S2-JJ	Tremont @ Cambden
S2-KK	Boston Gatehouse No. 1
S2-LL	Boston Gatehouse No. 2
S2-MM	MDC Fens Gatehouse

LEGEND (Continued)

Figure 8-5 Dorchester Interceptor System

54-A	Fuller & Clermont
54-B	Adams & Minot
54-C	Granite Avenue
54-D	Walnut & Woodworth
54-E	Neponset Avenue
54-F	Geneva Ave. & Tonawanda St.
54-G	Park & Marlowe
54-H	Park & Geneva
54-I	Dorchester Ave. & Gibson
54-J	Adams & Christopher
54-K	Park & Clayton
54-L	Freeport & Kimball
54-M	-
54-N	Kimball & Freeport
54-O	Bowdoin & Hamcock
54-P	Hancock & High
54-Q	Dorchester Ave. & Hoyt
54-R	Awkland & Hoyt
54-S	400' N. of Hoyt St.
54-T	Savin Hill & Awkland
54-U	Crescent & Carson
54-V	Crescent & Sidney
54-W	Morrisey Blvd. & Mt. Vernon

Figure 8-6 South Boston Interceptor (S. Branch) System

35-A	Farragut Rd. & E. Eighth
35-B	N St. & Marine Rd.
35-C	K St. & Marine Rd.
35-D	I St. & E. Eighth
35-E	H St. & Marine Road
35-F	Rev. Burke & Columbia Rd.
35-G	Old Colony Ave. & Gen. Logan Way
35-H	Sterling Square

are intermingled with large volumes of separate stormwater runoff long before reaching the apparent point of interception by the EMMA recommended facilities.

Figures 8-2 through 8-6 indicate that overflows occur rather far up in the combined sewer systems, typically at the connection of individual trunk sewers to the interceptors. It has been assumed generally, then, that the ultimate wet weather transmission limitations are not at the headworks or suitably repaired treatment plant pumping stations. They more likely will be the available excess interceptor capacities and individual regulator conditions. After headworks and pumping capacities equivalent to the available interceptor capacities are provided, no futher overflow reduction will result from additional pumping capacity.

Pollution Loadings and Water Quality Impacts

The data in Table 8-6 were developed for the Charles River Basin, the lower Mystic and Neponset Rivers and all of Boston Harbor, using coliform bacteria as the critical water quality parameter in these sections. The first two columns in this table are estimated coliform loadings for 1970 and for Alternative IC in the year 2000; the second two columns are the resulting coliform concentrations for these two conditions. The fifth column lists the water quality objectives for each section, expressed as coliforms/100 ml. The sixth column lists the percentage further reductions of loadings from the IC condition that would be necessary to satisfy the water quality objectives, and the final column translates these reductions into maximum allowable loadings for each section. Comparing these allowable loadings with the distributions among sources tabulated in Table 8-3 reveals the following.

- If combined sewer overflows were eliminated entirely, the allowable loadings in all river sections would still be exceeded by the separate urban stormwater runoff (allowable loading in Neponset section N3 is exceeded by Mother Brook inflow).
- Complete elimination of combined sewer overflows would satisfy the water quality objectives in all Boston Harbor sections.

TABLE 8-6

ALLOWABLE COLIFORM LOADINGS AND CONCENTRATIONS

	Coliform Loadings (lb/day)		Coliform Concentrations (numbers/100 ml)			Necessary Reduction (%)	Allowable Load (lb/day)
Section	Year 1970	Year 2000(IC)	Year 1970	Year 2000(IC)	Year 2000(ID) (objectives)	(%)	(lb/day)
C7	4.23	1.45	60,000	20,000	1,000	95	0.07
C8	15.52	5.60	50,000	20,000	1,000	95	0.28
M4	4.64	1.49	10,000	3,000	1,000	67	0.50
N3	1.27	1.29	60,000	60,000	1,000	98	0.02
BH1	10.49	4.18	6,000*	3,000	700	77	0.97
BH2	7.03	2.59	6,000*	2,000	700	65	0.90
BH3	0.35	0.36	50	40	70	-	0.36
BH4	10.15	0.15	700	100	700	-	10.0
BH5	0.01	0.02	160	46	700	-	5.0

*Highest concentration in section

- Considerably higher coliform loadings than are projected to result from alternatives IA, B and C can be tolerated for the Deer and Nut Island treatment plant effluents (projections are based upon effluent concentrations of 1000 coliforms/100ml and no sludge discharges).

Performance and annual cost projections for the first four stormwater and combined sewer overflow control alternatives (ID.1 through ID.4) are displayed in Figure 8-7. The ranges of performance and cost for each alternative represent the impacts of different technological assumptions. An assumption of a first flush phenomenon results in the lower costs for Alternatives ID.1 and ID.3, because less of the runoff and overflow volumes need to be retained and/or treated. The higher costs for these alternatives are based upon no first flush phenomena existing. Conversely, for street cleaning, Alternative ID.4, a first flush assumption, results in higher costs because the streets need to be cleaned at much higher frequencies in order to collect surface pollutants before they are washed away. The range for sewer flushing, Alternative ID.2, represents a completely combined system (higher costs) and a completely separate collection system discharging to combined interceptors (lower costs). For all levels of coliform reductions required to satisfy water quality in the Boston area, automated sewer flushing and intensive street cleaning are the least expensive of the first four control strategy alternatives.

For estimating costs and cleaning frequencies for intensive urban street cleaning operations, a 95% pollutant removal objective was used. This level of control is at the extreme unstable upper limit of the street cleaning dynamics model described in Appendix E, and upon which estimated costs and cleaning frequencies were based. Certainly the achievement of this level of control has yet to be demonstrated on any sizable scale. Nevertheless, the existing and projected water quality requirements, at least in the Charles River Basin, dictate that somehow this very high level of control will have to be achieved if water quality criteria are to be satisfied. Until the appropriate pollution source and control strategy performance data are collected and analyzed, the intensive street cleaning option still appears to be the most cost-effective alternative even approaching the levels of stormwater control

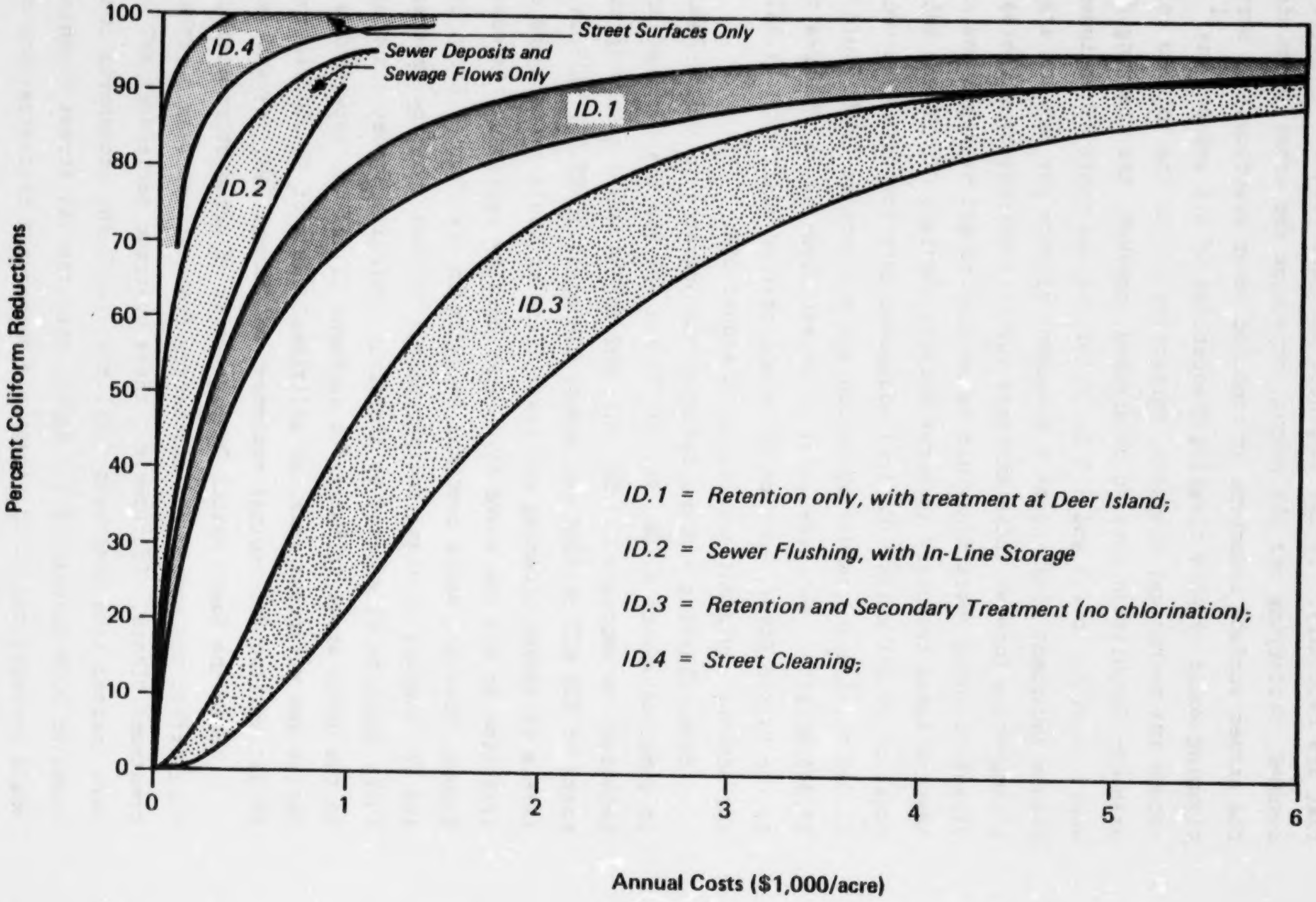


Figure 8-7 ID Control Alternatives Stormwater and Combined Sewer Overflows

that are necessary. If the suspended particle wash-off formulation is assumed, satisfying the 95% removal objective for urban stormwater (or the street surface component of combined sewer overflows) by street cleaning would require cleaning frequencies of 0.4 and 0.8 day^{-1} for vacuum and mechanical cleaners, respectively. If the soluble pollutant wash-off formulation were to be assumed, however, the cleaning frequencies would escalate to 2.8 and 5.0 day^{-1} for the two types of equipment. Vacuum equipment cleaning at a frequency of once per day was assumed as a compromise between these extremes for cost estimating purposes. This street cleaning operation would be applied to all separate and combined sewered areas tributary to water quality sections C7, C8 and BH1, a total of 24,541 acres. Capital equipment cost for this area would be $3.345 million and annual operation and maintenance (O&M) would be $3.343 million. The same level of street cleaning in the area tributary to the Mystic River, section M4, would cost an additional $1.152 million for capital equipment and $1.152 in annual O&M.

Sewer flushing systems designed and operated to reduce deposition in combined sewers by 98, 98, 80, 70 and 70% for the combined areas tributary to sections C7, C8, BH1, BH2 and M4 would result in capital costs of $38.622 million and annual O&M costs of $2.988 million. These levels of street cleaning and sewer flushing would satisfy the coliform criterion in all the above five water quality sections. Excessive algal blooms, however, would continue to exist in the Charles Basin (sections C7 and C8) because of algae and phosphorus inflows from the upstream sections. These would be eliminated by similarly intensive street cleaning programs in the urban areas tributary to sections C5 and C6, between the South Natick and Watertown dams, at additional costs of $6.254 million and $6.251 million for capital equipment and annual O&M, respectively.

Above the South Natick Dam, no level of urban stormwater control will offset the phosphorus discharges from the upstream peripheral treatment plants. If, however, these upstream peripheral AWT plants were instead land treatment facilities (effluent phosphorus concentrations of 0.05 instead of 1.0 mg/l), then the 95% street cleaning level would probably result in acceptable phosphorus concentrations and algal growth the length of the Charles River. This projection is based upon an assumption that the nonpoint source loadings are overstated substantially for the low-flow conditions modeled. The additional street cleaning costs for Charles River sections C1 through C4 would be $5.294 million for capital equipment and $5.292 million for annual O&M. No cost differential was assumed between AWT and land treatment for the upstream treatment plants.

The 95% street cleaning level in the urban areas tributary to the Neponset River would appear to result in satisfactory water quality in all but the uppermost reach of section N1, although coliform concentrations would still be marginal in section N3 if the DWPC 1973 survey data are correct.* Street cleaning at the 95% level in areas tributary to sections N2 and N3 would cost $3.501 million and $3.499 million for capital equipment and annual O&M, respectively.

Alternative ID.5: EMMA-Recommended Detention/Chlorination Facilities

The EMMA combined sewer overflow facilities were grouped according to their locations in water quality sections. The EMMA, Volume 7, Alternative 1, facilities are thus grouped below. (Alternative 1 was selected because of the potentially adverse effects of Alternatives 2 and 3 on the Class SA waters of Quincy Bay).

(ALTERNATIVE I)
EMMA-RECOMMENDED DETENTION/CHLORINATION FACILITIES

Section	EMMA Facility	Tributary Acres	Combined Acres	Separate Acres	Remaining Storm Drainage (acres)	Storage (inches)
C7	1	875	226	649	4443	0.24
C8	2	980				
	3	7550				
		8530	2237	6293	2086	0.04
BH1	4	330				
	5	400				
	6	525				
	7	2960				
		4215	3029	1186	2502	0.11

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*The available evidence indicates that the reported 1973 data may be high by an order of magnitude (DWPC 1976).

(ALTERNATIVE I) (CONTINUED)

Section	EMMA Facility	Tributary Acres	Combined Acres	Separate Acres	Remaining Storm Drainage (acres)	Storage (inches)
BH2	8	1075				
	9	1580				
	10	720				
		3375	1583	1792	1388	0.14

The tributary areas to these facilities were subdivided into combined and separate sewered areas. There remains some ambiguity as to whether the separate areas are separate sanitary or separate storm sewered areas. Conversations with Metcalf & Eddy personnel indicated that the separate areas would be separate storm sewered areas, from which flows would enter the system prior to interception by the EMMA facilities. These facilities, therefore, would also detain and chlorinate varying fractions of the separate stormwater runoff from each area, although reducing the available detention volume for combined sewage in the process. The above data were developed on this basis. Runoff from all combined sewered areas was assumed to flow initially to Deer Island, up to the available wet weather interceptor capacity of 0.37 inch/day. All excess flows would be diverted, along with the designated portion of runoff from separate storm sewered areas, to the detention facilities. The available storage for combined sewer overflows was assumed proportional to the ratio of combined to total drainage areas for each group of facilities.

Equations (2) and (4) from Appendix F were used to project the pollutant reductions from street surfaces and sewer deposition, respectively, due to detention of combined sewer overflows by these facilities, with all subsequent treatment at Deer Island. BOD, phosphorus and coliform bacteria in the remaining overflows were then assumed to be reduced by 20, 0 and 90%, respectively, as for the Cottage Farm and Charles River Estuary facilities. No additional interceptor capacities were assumed for the separate stormwater entering the facilities during wet weather, so pollutant removals were considered to be the same as for combined sewage flowing through the facilities: 20, 0 and 90% for BOD, phosphorus and coliforms. The resulting loadings to each of the impacted water quality sections are summarized in Table 8-7.

Water Quality Impacts

The EMMA-recommended facilities will not satisfy the coliform objectives in the Charles River Basin, primarily because the remaining separate stormwater contributes more than enough bacteria to violate the criterion. There would, furthermore, be enough remaining phosphorus loading to the Charles Basin to create excessive algal blooms and, although not modeled, the dissolved oxygen criterion would probably also be violated because of the large remaining BOD loadings. The bacterial quality criteria in all Boston Harbor sections, however, would be satisfied by the EMMA approach, although dissolved oxygen may become the limiting parameter in the Inner Harbor. Capital and annual O&M costs, from the EMMA study, are estimated at $279.4 million and $3.9 million, respectively.

8.4 Alternative IE: Secondary Treatment at Deer and Nut Islands

The secondary treatment alternative was included in this category for three reasons.

- Region I EPA has concentrated upon the enforcement of the Section 301 requirement for secondary treatment at the Harbor treatment plants, even though all existing water quality studies and analyses indicate the major sources of Boston Harbor water quality problems to be elsewhere.
- The existing primary treatment plant effluents would avoid violations of Boston Harbor water quality only because of effluent chlorination.
- Some questions need to be raised about the Boston area acceptance of chlorination as a panacea for complex and serious water pollution problems.

TABLE 8-7

ALTERNATIVE ID.5 EMMA RECOMMENDED APPROACH TO COMBINED SEWER OVERFLOWS POLLUTANT LOADINGS (lb/day)

	BOD_5			Phosphorus			Total Coliforms			
Section	SS	CSO	T	SS	CSO	T	SS	CSO	T	OBJ
C7	1800	19 39	1858	58	1 1	60	1.03	0.002 0.02	1.05	0.07
C8	1672	336 639	2647	92	23 16	131	0.60	0.05 0.39	1.04	0.28
BH1*	597	338 495	1430	44	24 10	78	0.62	0.05 0.30	0.97	0.97
BH2*	482	135 357	974	29	10 7	46	0.29	0.02 0.15	0.46	0.90

SS = separate stormwater
CSO = combined sewer overflow (streets and sewer depositions)
T = total
OBJ = objective
*point sources and nonpoint sources not included

EPA Region I has long been determined that the Deer and Nut Island treatment plants be upgraded to secondary treatment, according to the effluent limitation specified in Section 301(b)(1)(B), PL 92-500, for publicly owned treatment works. At the same time, Region I and other Boston area pollution control agencies have accepted in the EMMA-recommended Plan a far more primitive level of treatment for the raw sewage overflows from publicly owned combined sewer systems. The perverse result of this inconsistent specification of effluent limitations is that massive volumes of raw sewage need only be detained and chlorinated for 15 minutes before overflowing to small rivers and the Boston Harbor waterfront, but, if these same volumes of raw sewage were pumped to Deer Island, they would require secondary treatment before they could be discharged into the huge tidal interchanges of the Boston Outer Harbor. If chlorination of the combined sewage overflowing to the Charles River Basin is acceptable "treatment", logic surely should dictate that the same treatment would be acceptable for the primary effluents discharging to the Outer Harbor. It can be argued that this "treatment" should be unacceptable in both cases.

The Federal Safe Drinking Water Act, PL 93-523, was legislated into existence immediately upon the discovery of carcinogenic chlorinated organic compounds in virtually all public water supplies in the United States. The concentrations of known carcinogenic compounds resulting from the chlorination of sewage effluents are large. The widespread presence of tumors in fish and shellfish in natural waters used for wastewater disposal is recently, though increasingly, being detected. The toxicity of chlorine itself to both marine and freshwater biota is clearly recognized in EPA's Water Quality Criteria. The NPDES permits for Deer and Nut Island effluents, for example, require that "the total chlorine residual of the effluent shall not result in any demonstrable hazard to aquatic life. . . ." The state of Maryland requires that chlorine residuals in treated effluents not exceed 0.5 mg/l for discharges into recreational use waters and not exceed 0.01 mg/l for discharges to sensitive gamefish habitats. This contrasts with the NPDES permits for the EMMA combined sewer overflow facilities, which require a minimum chlorine residual of 1.0 mg/l. There is reason to suspect that even the disinfection presumed as the benefit derived from chlorination of primary or lesser treated effluents may be a mirage. No virologist contacted during this case study would agree that any significant virus destruction could be achieved in this application. Virus particles are too well shielded by the large solids concentrations remaining in primary sewage effluents (without considering combined sewer overflows) for chlorination to be effective. Chlorination simply destroys the coliform bacteria, whose existence would subsequently be relied upon to indicate the probable presence of the more dangerous organisms. The Boston Harbor coliform criteria may indeed be satisfied by chlorinated primary effluents; the fate of the sorts of pathogens in these effluents, for example, hepatitus viruses, known to accumulate in the harbor shellfish, has not been monitored.

Secondary treatment, because of its additional solids removal capability and increased provision for biological oxidation, reduces coliforms, and presumably viruses and other pathogens as well, two orders of magnitude below that achieved in primary treatment (see Section 5.2). The tidal interchange in Boston Harbor averages, over a 6-hour tidal half-cycle, about 320,000 cfs (Process Research, Inc. 1976). For the 906 cfs (586 mgd) harbor treatment plant effluents, this interchange would provide a dilution of about 350/1. The Boston Harbor Model described in Appendix D, which was developed quite empirically, projected a total allowable coliform loading rate from Deer and Nut Islands of 15 lb/day, based on a water quality criterion of 700 coliforms/ 100 ml. Diluting this 15 lb coliforms per day into 320,000 cfs results in a concentration of 872 coliform/100 ml. This degree of agreement between two such simple models is due to the fact that the exponential coliform die-off implicit in the empirical Boston Harbor Model compensates for the exponential dilution that a more sophisticated dilution model would employ. The unchlorinated effluents from the Deer and Nut Island primary treatment plants would contain about 49 lb/day of coliform bacteria (at concentrations of 10^6/100 ml), substantially in excess of the tolerable 15 lb/day from these facilities. Unchlorinated secondary effluents, on the other hand, would contain only about 0.5 lb/ day of coliform bacteria and would be easily acceptable at the present discharge locations. Discontinuance of the present reliance on chlorination as the sole pathogen control agency would result in a requirement for secondary treatment at Deer and Nut Islands, a requirement that would be dictated solely by demonstrable water quality considerations.

The additional costs of secondary treatment under this alternative, for the baseline flow conditions were estimated by scaling down the EMMA study estimates for secondary treatment as follows:

ESTIMATED COSTS FOR ADDITION OF SECONDARY TREATMENT
OF BASELINE FLOWS (ALTERNATIVE IE)

Facility	Flow (mgd)	Capital Cost ($ Millions)	Annual O&M ($ Millions)
Deer Island STP	312	120	3.0
Nut Island STP	136	90	1.5
Sludge Management	-	25	0.7
Total Costs		235	5.2

8.5 Category II: EMMA-recommended Plan

The principal initial difficulty with the EMMA-recommended plan is that the year 2000 flow projections developed by the EMMA study do not appear to allow any excess wet weather interceptor capacities for bypassing or emptying the proposed (or existing) combined sewer detention/chlorination facilities. The EMMA-projected dry weather flow in the Dorchester Interceptor, for example, is almost precisely its existing full pipe design capacity. With no available wet weather interceptor capacities for the detention/chlorination facilities, no significant overflows could be contained. With no available interceptor capacities, the additional pumping capacity included in Alternative IIB would not be able to provide any further reductions in overflows either. The only modifications in pollutant loadings listed in Tables 5-4, 5-5 and 5-6 will be the 20, 0 and 90% reductions in BOD, phosphorus and coliforms assumed for combined sewer overflows passing through these facilities (no BOD or phosphorus removals were assumed for the Somerville

Pretreatment Facility), and the same reductions for the portions of separate stormwater passing through the facilities. Coliform loadings to the water quality sections affected by these facilities are compared with the 1970, Alternative IC and allowable loadings in Table 8-8. The EMMA-recommended plan (EMMA CSO Alternative 1) exceeds the allowable coliform loadings at all locations except section BH2 (Dorchester Bay) and section BH3 (Quincy Bay).

Phosphorus loadings to the upstream river sections for 1970, Alternative IC and the EMMA-recommended plan are compared in Table 8-9. Also shown on this table are the total phosphorus loadings that would result if all peripheral sewage treatment plants were land treatment facilities instead of AWT. Table 8-10 summarizes phosphorus concentrations at the inlet and outlet of each of the upper Charles River sections resulting from the EMMA AWT satellite plant and the peripheral AWT plants. Two locations were examined for the EMMA satellite: one at the inlet of section C5 as recommended by EMMA and another further upstream at the inlet of section C4 near the Stop River. There are slight but not great differences in phosphorus concentrations between the two locations. Also included in this table are phosphorus concentrations projected to result from the elimination of the Mother Brook diversion. While the differences again are not great, the concentrations entering the Basin downstream (section C7) would be slightly higher if the diversion were eliminated and stormwater control measures in sections C5 and C6 were not put into effect. By most measures, the Charles River at the Mother Brook diversion is of poorer quality than the Neponset, and with the EMMA-recommended plan, is projected to continue to be. The Mother Brook diversion does not, therefore, appear to enhance water quality downstream in the Neponset River. Shifting the peripheral AWT plants on the Charles River to land treatment facilities (effluent phosphorus from 1.0 to 0.05 ml/l) would not in itself improve water quality sufficiently in the upper Charles River. Land treatment coupled with the 95% level street cleaning program as described in Alternative ID would result in acceptable water quality in the Charles River down to the EMMA satellite location. From there on downstream, however, phosphorus concentrations would be excessive. There is simply no location along the Charles River that will tolerate a phosphorus discharge of 1.0 ml/l in a flow of any magnitude.

TABLE 8-8

ALTERNATIVE II: EMMA-RECOMMENDED PLAN
TOTAL COLIFORM LOADINGS (lb/day)

Section	Year 1970	Alt.IC	EMMA	Allowable
C7	4.23	1.45	1.10	0.07
C8	15.52	5.60	1.78	0.28
M4	4.64	1.49	1.63	0.50
N3	1.27	1.29	1.29	0.02
BH1	10.49	4.18	1.60	0.87
BH2	7.03	2.59	0.74	0.90
BH3	0.35	0.36	0.36	0.36

TABLE 8-9

ALTERNATIVE II: EMMA-RECOMMENDED PLAN
PHOSPHORUS LOADINGS (lb/day)

Section	Year 1970	Alt.IC	EMMA As Recommended	EMMA w/Land Treatment
C1	24	28	28	28
C2	101	49	49	20
C3	151	176	176	105
C4	152	193	193	162
C5	60	72	332	332
C6	211	244	244	244
M1	80	91	91	91
M2	16	16	16	16
M3	51	53	53	53
N1	104	118	118	114
N2	125	148	358	355

TABLE 8-10
ALTERNATIVE II EMMA RECOMMENDED PLAN CHARLES RIVER PHOSPHORUS CONCENTRATIONS

	Satellite at C5		Satellite at C4	
Section	C_o	C_t	C_o	C_t
C1	-	1.97	-	1.97
C2	1.03	0.64	1.03	0.64
C3	0.83	0.93	0.83	0.93
C4	0.91	1.07	0.97	1.00
C5	1.02	0.77	1.00	0.76
C6	0.77	0.68	0.76	0.69
C6*	0.77	0.70	0.76	0.70
AWT PLANTS ONLY				
C1	-	-	-	-
C2	0.88	0.31	0.88	0.31
C3	0.71	0.33	0.71	0.33
C4	0.45	0.22	0.78	0.56
C5	0.67	0.42	0.56	0.35
C6	0.42	0.15	0.35	0.13
C6*	0.42	0.19	0.35	0.16
URBAN STORMWATER ONLY				
C1	-	1.55	-	1.55
C2	0.12	0.20	0.12	0.20
C3	0.07	0.42	0.07	0.42
C4	0.32	0.66	0.13	0.34
C5	0.27	0.29	0.34	0.34
C6	0.29	0.49	0.34	0.51
C6*	0.29	0.47	0.34	0.49
NON-POINT SOURCES ONLY				
C1	-	0.42	-	0.42
C2	0.03	0.13	0.03	0.13
C3	0.05	0.18	0.05	0.18
C4	0.14	0.19	0.06	0.10
C5	0.08	0.06	0.10	0.07
C6	0.06	0.04	0.07	0.05
C6*	0.06	0.04	0.07	0.05

*Mother Brook diversion eliminated

The EMMA satellite AWT plant on the Neponset River similarly will degrade water quality because the additional flow from the treatment plant would contain an order of magnitude higher phosphorus concentration than is now present in the Neponset River at the proposed discharge location.

8.6 Category III: Alternatives to the EMMA-recommended Plan

The water quality impacts of all the Category III alternatives are variations of impacts already described under Categories I and II. All of these alternatives include the EMMA-recommended approach to control of combined sewer overflows.

Alternative IIIA: EMMA without the two satellite plants; satellite flows to Nut Island for secondary treatment; with and without Mother Brook diversion.

If the EMMA flow projections are accepted, the water quality impacts of this alternative would not be greatly different from those of the EMMA recommended plan, described as Alternative II: water quality criteria will be satisfied in all Boston Harbor sections except the Inner Harbor, and nowhere else. If the reduced flow projections assumed in Alternative I, baseline conditions, are accepted then the coliform criterion in Boston Inner Harbor, section BH1, will also be satisfied. Dissolved oxygen, however, may then become the limiting criterion in the Inner Harbor. Water quality in section N3 of the Neponset River would benefit slightly from the elimination of the Mother Brook diversion, but not enough to satisfy the coliform bacteria criterion.

Alternative IIIB: EMMA with two satellite secondary treatment plants; effluents piped to ocean discharge; with and without Mother Brook diversion.

Water quality impacts of this alternative are indistinguishable from those of Alternative IIIA.

Alternative IIIC: EMMA with two satellite secondary treatment plants discharging directly to the Charles and Neponset Rivers; eliminate Mother Brook diversion.

This alternative, which involves the discharge of 2,200 lb/day of phosphorus to the Middle Charles River and 1,800 lb/day to the upper Neponset would ensure the growth of massive algal blooms throughout the downstream sections of both rivers. The resulting phosphorus concentrations entering the Charles Basin, section C7, for example, would be in excess of 2 mg/l, ten times the present concentrations at that point. If it is not possible to satisfy water quality criteria in these rivers with AWT effluents, secondary effluents will be even more unacceptable.

Alternative IIID: EMMA with two satellite land treatment plants; eliminate Mother Brook diversion.

The two land treatment facilities considered in this alternative were of the same design capacities as the EMMA satellite AWT plants, 31 mgd on the middle Charles and 25 mgd on the upper Neponset. The land disposal areas were assumed to be located within 20 miles of the proposed EMMA satellite locations; force mains, pumping stations and open return flow channels were costed with this assumption. A 7-month application period was assumed, so that actual application rates during the summer low flow periods would be nearly twice the average daily inflow of sewage. Typically, only about half the applied sewage is recovered in the underdrain system, because of evapo-transpiration and losses to groundwater, so the average return flow during the application period was assumed equal to the average daily sewage inflow. The land treatment systems, in fact, offer considerable flexibility in this regard, since it is possible to reduce return flows to the rivers to zero and allow the entire application (less evapo-transpiration) to be used for ground water recharge. Effluent characteristics of land treatment return flows are those listed previously in Section 5. Cost estimates for the two satellite land treatment facilities are summarized in Table 8-11 (see Appendix H for details). It was not assumed that the

TABLE 8-11

SATELLITE LAND TREATMENT FACILITIES

COST ESTIMATES: ALTERNATIVE III D.

CAPITAL COSTS
($ Million)

	Item	Middle Charles	Upper Neponset
1.	20-miles force main	7.70	6.60
2.	Pumping stations	2.09	1.93
3.	20-miles open return flow channel	1.30	1.14
4.	Aerated lagoons	0.80	0.69
5.	5-month storage lagoons	6.05	5.39
6.	Center pivot application systems	12.10	9.90
7.	Underdrains	3.30	2.53
8.	Land cost ($2000/acre)	14.07	11.35
	Total Capital Costs:	48.04	39.53
	EMMA Comparable Costs:*	42.26	35.38

OPERATION & MAINTENANCE
($ Millions/year)

	Item	Middle Charles	Upper Neponset
1.	Force mains	0.012	0.011
2.	Pumping stations	0.224	0.181
3.	Open return flow channels	0.025	0.024
4.	Aerated lagoons	0.205	0.167
5.	Storage lagoons	0.040	0.033
6.	Application systems	0.747	0.602
7.	Underdrains	0.047	0.040
8.	Farming costs	0.446	0.360
9.	Crop revenues	(0.661)	(0.533)
	Total O&M Costs:	1.085	0.885

*The cost estimate developed in the EMMA Study did not include costs of land upon which treatment facilities would be constructed. Subtracting all nontreatment land costs from the above total cost results in these EMMA comparable cost estimates.

land application sites for each facility would necessarily be limited to one. The 20 miles of force mains and return flow channels were added with the assumption that application sites would be distributed, in increments not larger perhaps than 1,000 acres, within 10 to 20 miles of the rivers. No specific sites were located or sought, although the EMMA Study (Volume 5) located a number of potential spray irrigation sites within 20 miles of the proposed EMMA satellite locations.

Since the Upper Neponset Facility would be discharging 38.7 cfs with a phosphorus concentration of 0.05 mg/l into about 10 cfs (approximate 10-year, 7-day low flow in the Neponset without Mother Brook) with a phosphorus concentration of 0.10 mg/l, water quality downstream in sections N2 and N3 would become acceptable as far as phosphorus and algal growth is concerned. With rigorous street cleaning for urban runoff control, and all present Neponset River point-source discharges diverted to the land treatment satellite, these Neponset River sections would probably satisfy all Class B water quality criteria.

For the Upper Charles River, a number of gradations in scenarios were examined. The resulting phosphorus concentrations along the river (sections C1 through C6) are displayed in Figure 8-8. The first option (IIID.1), for comparison purposes only, is the recommended EMMA plan, Alternative II, with the Mother Brook diversion eliminated. The second option (IIID.2) is the 31 mgd satellite land treatment facility, located at the entry to water quality section C5 (vicinity of South Natick Dam). In Option IIID.3, all upstream AWT facilities are also converted to land treatment. Option IIID.4 adds the 95 percent level urban stormwater control. In Option IIID.5, the satellite land treatment facility discharge point is moved upstream to the inlet of section C4. In Option IIID.6, the nonpoint source loadings were ignored. If this latter assumption is correct for low flow periods, it is possible to achieve the phosphorus and algal concentration objectives in the upper Charles, but only with the complete conversion to land treatment systems and very intensive street cleaning operations. It is also worthy of observation from Figure 8-8 that the further upstream the satellite land treatment discharge is located, the better is the overall downstream water quality. Water quality considerations alone, therefore, would dictate that sewage

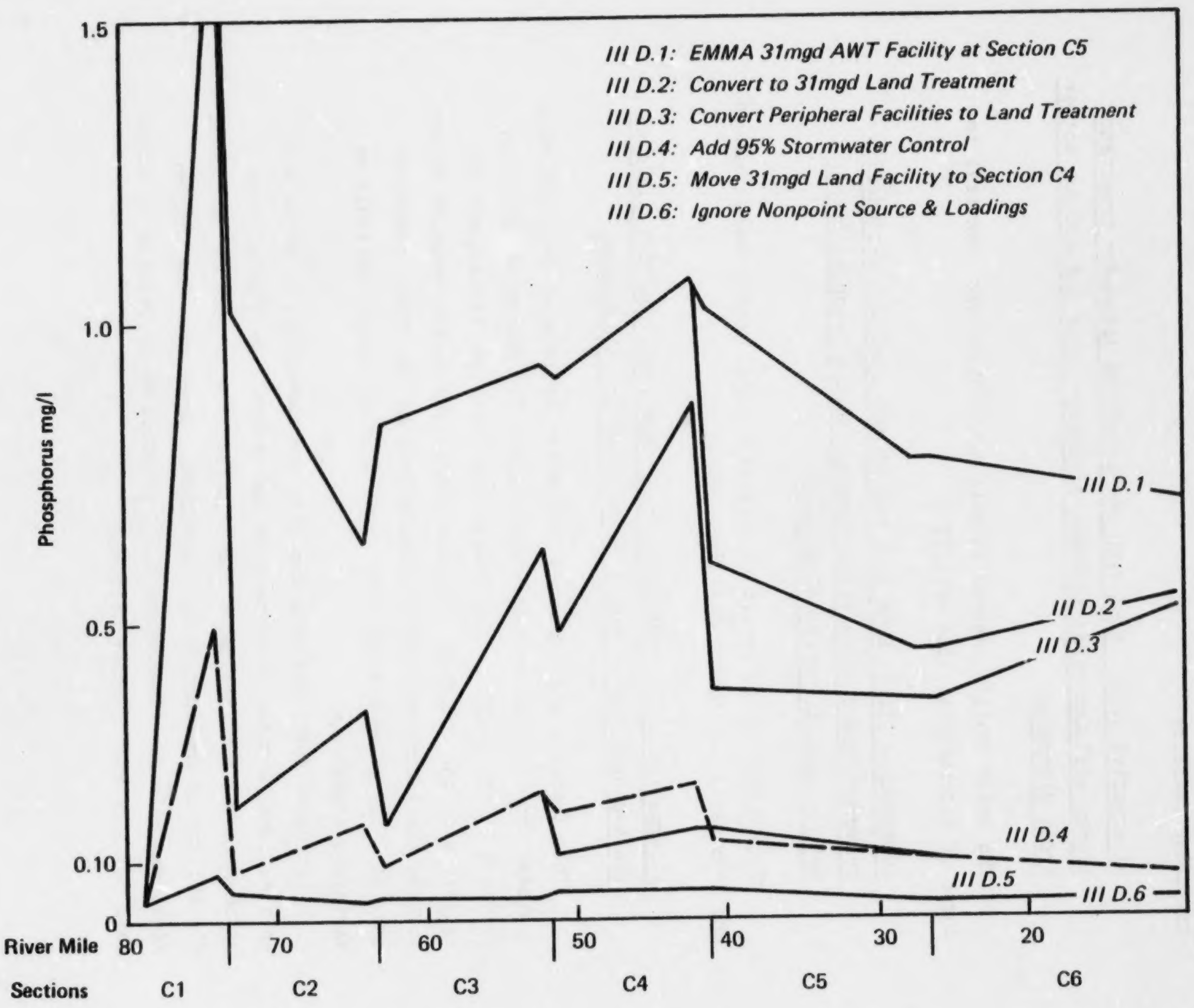

Figure 8-8 Charles River Phosphorus Concentrations for Option IIID - Strategy Combinations

collected in Wellesley and other downstream communities should be pumped back upstream where land application sites would presumably be more readily available. This would be true also of the Neponset River land treatment facility.

Alternative IIIE: EMMA with one satellite secondary treatment plant; effluent piped to ocean discharge; with and without Mother Brook diversion.

The water quality impacts of this alternative are identical to those of Alternatives IIIA or IIIB.

Alternative IIIF: EMMA with one 56 mgd satellite secondary treatment plant discharging directly to the Neponset River; Mother Brook diversion eliminated.

This option would result in excessive algal growth downstream in the Neponset River (see Alternative IIIC).

Alternative IIIG: EMMA with one 56 mgd land treatment plant on the Neponset River; Mother Brook diversion eliminated.

This facility was initially assumed to be located about one mile upstream from the Mother Brook confluence. The additional dilution provided by the facility (10-fold at low flow) may be adequate to satisfy even the coliform criterion downstream in the Neponset River without the intensive street cleaning program for urban stormwater control. All other criteria for Class B waters would certainly be satisfied downstream.

Estimated costs for this facility are summarized in Table 8-12. An additional 5 miles of force main and return flow channel were assumed in the cost estimates for this facility to provide additional flexibility of application site location. Based upon the Charles River analysis for Alternative IIID, it would be preferable to locate this facility much further upstream.

TABLE 8-12

56 MGD SATELLITE LAND TREATMENT FACILITY ESTIMATES COSTS (ALTERNATIVE III G)

Item	Capital Costs ($ million)	Operation & Maint. Costs ($ million/year)
25-mile force main	13.75	0.021
Pumping station	3.52	0.393
25-mile open return flow channel	2.20	0.034
Aerated lagoon	1.32	0.361
5-month storage lagoon	10.12	0.067
Center pivot application systems	20.90	1.237
Underdrains	5.50	0.074
Land cost ($2000/acre)	25.42	0.806
Crop revenues	-	(1.193)
Total	82.73	1.800
EMMA Comparable Cost*	73.43	

*See footnote, Table 8-11

Alternative IIIH: EMMA with one 56 mgd satellite AWT Plant discharging directly to the Neponset River; eliminate Mother Brook diversion.

As with Alternative IIIG, the additional dilution provided by this facility may result in the downstream coliform criterion being satisfied. The resulting phosphorus concentrations, however, would continue to be excessive and so would the algal growth.

Alternatives IIIJ and IIIK: Expanded primary treatment at Deer and Nut Islands; no satellite plants; deep ocean discharges (IIIJ) or discharges to present locations (IIIK).

The water quality impacts of these two alternatives would not be measurably different from Alternatives IIIA or IIIB, by the assumptions for chlorinated effluents used in most of this analysis, in the EMMA study and by the Deer and Nut Island NPDES permits. If these assumptions, however, are questioned as was described under Alternative IE, then the water quality impacts of IIIJ and IIIK would become quite different. If chlorination is discounted as an effective pathogen control process for primary effluents, then Alternative IIIK would violate water quality criteria for coliforms throughout all Boston Harbor sections and Alternative IIIJ, deep ocean discharge would be required.

9. WATER QUALITY BENEFITS OF ALTERNATIVE INVESTMENT STRATEGIES

9.1 Priorities for Meeting Water Quality Objectives

Section 303(d) of PL 92-500 requires each state to establish a priority ranking for water-quality-limited stream segments, that is, those waters "for which the effluent limitations required by Section 301(b)(1)(A) and Section 301(b)(1)(B) are not stringent enough to implement any water quality standard applicable to such waters," such ranking "taking into account the severity of the pollution and _the uses to be made of such waters_" (emphasis added).

The Massachusetts DWPC priority ranking system, included in its basin plans, is based upon a point system (0 to 3) indicating the "severity" of the pollution of a given segment according to eight separate parameters: coliforms, dissolved oxygen, solids/color, nutrients, pH/metals, temperature, other and class violation. The "severity points" are summed over the eight parameters and multiplied by the length of the segment to provide a relative "severity rating" for each segment in a given river basin. The fractional impact of each pollution source on each segment is then estimated, multiplied by the respective segment "severity ratings" and summed to result in a ranking of "total severity points" for each pollution source in the basin.

Thus, there can be said to exist within the DWPC basin plans a priority ranking of stream segments (water-quality-limited as well as effluent-limited segments) and also pollution control projects. Construction grant priorities in Massachusetts, however, have historically been based more upon a municipality's willingness to proceed, because, until 1977, there have been more available dollars than there have been available high priority projects. Nevertheless, even such priority ranking systems as exist have been weighted heavily toward severity of pollution at the expense of potential water uses. Only one of the eight equally weighted rating parameters (class violation) may be said to be associated with water use.

An alternative priority ranking system, intended to be weighted more evenly in the direction of water use or potential benefits, was developed during this case study. Interviews with local environmental groups, watershed associations and others and reviews of existing Boston area willingness-to-pay (Gramlich 1975) and recreational benefit (Battelle 1976; Binckley and Hanemann 1976) analyses indicated that public priorities are influenced primarily by public proximities. The nearer (that is, more accessible) a given body of water is to the individual respondent, the more he is willing to pay for its cleanup or for the continued maintenance of an already acceptable quality. This correlation has been consistently found to be independent of the conventional age, ethnic or socioeconomic factors, or even of any previous or intended personal use beyond the knowledge of its potentiality. The water use potential model, described in Appendix I, was therefore a population distribution model based upon the relative distances between Boston area census tract populations and all possible locations for acceptable quality water. The function of this model was to distribute among the 19 water quality sections analyzed in this study those fractions of the total Boston metropolitan area population most likely to "use" or be otherwise benefited by acceptable quality water in each section, under the assumption that equally acceptable water would be available at all other locations within the metropolitan area.

These population distributions, computed by equation (2) in Appendix I, are summarized for the 19 water quality sections in Table 9-1. The final column in this table lists the population distributions per mile of section length. By this mile-to-mile comparison, the Charles River Basin is clearly the most beneficial location for swimming/fishing quality water in the Boston metropolitan area, followed by the Mystic River, Mystic Lakes, lower Neponset River and the Dorchester Bay section of Boston Harbor. The population use potentials along the length of the Charles River are displayed in Figure 9-1. They are compared in this figure with the DWPC system of severity points established in the Charles River basin plan (this basin plan does not include the Charles River Basin). The two alternative ranking systems can be seen in this comparison to indicate two quite different sets of priorities.

The recreational benefit analysis conducted by Binckley and Hanemann (1976) estimated the mean annual willingness to pay for recreational quality (swimming, fishing) water in the Boston metropolitan area to be $42.85 per capita. Multiplying this individual willingness to pay by

TABLE 9-1

RELATIVE USE (BENEFIT) POTENTIALS OF WATER QUALITY SECTIONS

Water Quality Section	Use Potential Segments (see Appendix I)	Population Distributions* (1,000's)	(1,000's/mile)
Charles			
C1	15	18	3.4
C2	14, 13	40	3.8
C3	12, 11	48	4.5
C4	10, 9	55	5.2
C5	8, 7, 6	172	10.8
C6	5, 4, 3	222	14.0
C7	2	142	26.8
C8	1	193	36.4
Mystic			
M1	68, 69	151	13.7
M2	51 (1/2)	68	24.7
M3	51 (1/2)	67	24.4
M4	50	151	27.5
Neponset			
N1	21, 20, 19	101	6.7
N2	18, 17	156	15.6
N3	16	109	21.8
Boston Harbor			
BH1	56, 55	121	15.1
BH2	57	85	21.2
BH3	69, 58	49	6.1
BH4	52, 53, 54	148	12.3

*Calculated from Equation (2), Appendix I.

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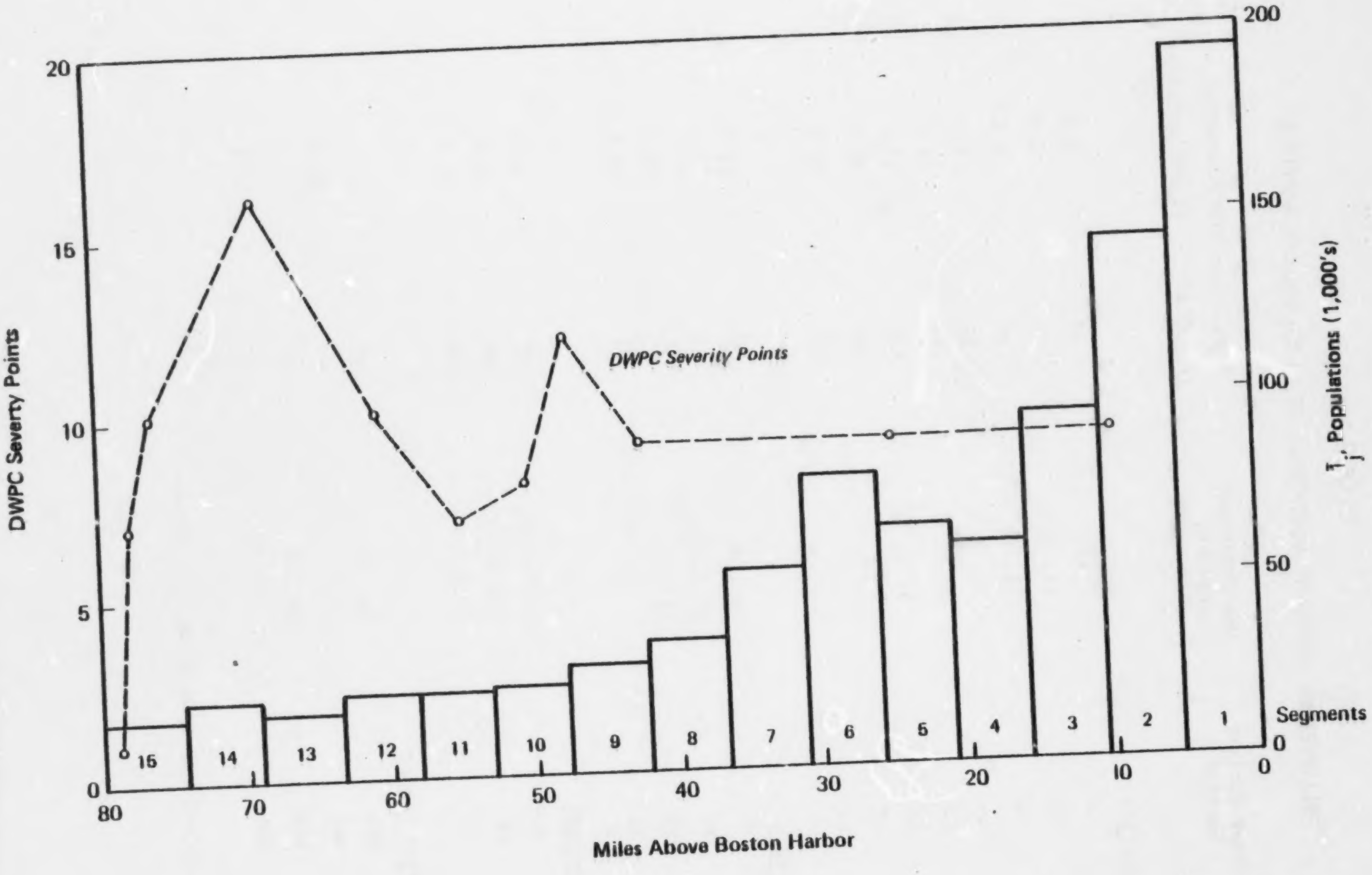

Figure 9-1 Population Use Potentials on Charles River

the population distributions in Table 9-1 provided an estimate in clear economic terminology, of the expressed public valuation of the annual benefits of recreational quality water in each of the 19 sections. These expressed clean water benefit valuations could then be compared, in a conventional benefit/cost analysis, with the estimated costs of satisfying the clean water criteria for each section and still a third priority ranking was developed. This benefit/cost based priority ranking, however, accounts for the severity of pollution and the anticipated uses in equivalent, quantitative and readily appreciated terms: dollars.

9.2 Present Worth Calculations

Estimated pollution abatement costs and resulting water quality benefits were compared in this analysis on a present worth basis, in accordance with EPA Cost Effectiveness Analysis Guidelines (Appendix A of 40 CFR, Part 35, Subpart E). These present worth calculations involved the following assumptions and computations:

a) interest rate at 7%;

b) 20 year planning period, from January, 1981 to December, 2000;

c) facilities service lines -

   1. pipelines, 50 years
   2. treatment plants and pumping stations, 30 years
   3. sewer flushing equipment, 30 years
   4. street cleaning equipment, 15 years;

d) zero inflation considered;

e) salvage value based on straight-line depreciation beginning at end of construction period;

f) annual benefits realized and uniform O&M costs incurred beginning at end of construction period (beginning of operations);

g) all cost and benefit estimates referenced to January, 1975 base date (ENR 2200) for comparison with EMMA study cost estimates and

h) time streams of costs and benefits were discounted back to January, 1975 base date.

Construction and implementation schedules for all alternatives to the EMMA Recommended Plan were assumed to be identical to the EMMA construction staging schedule. In the one exception to this assumption, sewer flushing and street cleaning operations in areas tributary to Boston Inner Harbor were assumed to be phased into place over the period scheduled for construction of the EMMA recommended Charles River, Neponset River and Dorchester Bay detention chlorination facilities. Acquisition of street cleaning equipment was considered to be phased over the EMMA construction period for these facilities, so the equivalent of interest costs during construction was included for this equipment acquisition. The equipment was considered, on the average, to be placed in service at the EMMA mid-construction period date, and the average age of equipment for salvage value purposes was computed from this date.

Descriptions and the relevant construction scheduling parameters for the Category I alternatives are summarized in Table 9-2, along with estimated incremental costs and respective present worths of each increment. Descriptions, cost estimates and present worths (computed by Kennedy Engineers, Inc.) are summarized in Table 9-3 for the Category II and Category III alternatives.

The present worths of the estimated benefits from acceptable quality water were computed as follows.

a) Annual benefits were assumed to begin accruing for each water quality section upon completion of construction of the alternative (or portion of the alternative) that upgraded that section to acceptable quality;

b) annual benefits for acceptable water in a given section were the product of the population distributed to that section and its willingness to pay ($42.85 per capita);

c) this uniform series of benefits from date of construction completion to December, 2000 was calculated and

d) the time stream of benefits was discounted back to the base reference period: January, 1975.

TABLE 9-2

CATEGORY I ALTERNATIVES SUMMARY

Alternative	Description	Construction Period (months)	Construction Completion Date	Incremental Costs ($ millions) Capital	O&M	Present Worth
IA.	Baseline upgrading, rehabilitation of existing systems; present service areas only; 1.5 hours detention at Deer I. (215 mgd) and Nut I. (115 mgd)	37	6/84	404.8	9.9	238.4
IB.	Expand Deer I. and Nut I. primary treatment to 2.0 hours detention time; present service areas only; Deer I. (215 mgd) and Nut I. (115 mgd)	37	6/84	12.8	1.3	9.9
IC.	Expand service to EMMA projected areas; 2.0 hours detention at Deer I. (212 mgd) and Nut I. (136 mgd)	37	6/84	51.0	0.5	30.2
ID.	Add 100 mgd wet weather treatment capacity to Deer Island; 2.0 hours detention at Deer I. (312 mgd)	37	6/84	75.5	9.0	52.4
ID.2&4a	Sewer flushing in areas tributary to C7, C8, M4, BH1, BH2; street cleaning in areas tributary to C7, C8, M4, BH1	25	1/83	41.9	6.3	62.1
ID.4b	Street cleaning in areas tributary to C5, C6	25	1/83	6.2	6.2	40.7
ID.4c	Street cleaning in areas tributary to N2, N3	25	1/83	3.5	3.5	23.0
ID.4d	Street cleaning in areas tributary to C1, C2, C3, C4; All peripheral treatment is land treatment instead of AWT (NPS ignored during low flow)	37	6/84	5.3	5.3	30.5
ID.5	EMMA recommended detention/ chlorination facilities: Dorchester Bay, Charles River, Neponset River, Boston Inner Harbor	21 37	1/83 12/85	270	3.9	175.8
IE.1	Secondary treatment for dry and wet weather flows at Deer I. (315 mgd) and Nut I. (115 mgd); present sewer service areas only	43	5/85	230	4.9	150.1
IE.2	Secondary treatment for dry and wet weather flows at Deer I. (312 mgd) and Nut I. (136 mgd); expanded service to EMMA projected areas	43	5/85	235	5.2	154.2

TABLE 9-3

ALTERNATIVE SUMMARY FOR CATEGORIES II AND III

		Estimated Costs ($ Millions)		
Alternative	Description	Capital	O&M	Present Worth
IIA.	EMMA Recommended Plan: secondary treatment at Deer I. (400 mgd) and Nut I. (130 mgd); satellite AWT in middle Charles (31 mgd) and upper Neponset (25 mgd); detention/chlorination of combined sewer overflows	855.4	25.6	603.0
IIB.	EMMA Recommended Plan with additional modifications and rehabilitation suggested by Kennedy Engineers	959.6	39.3	653.3
IIIA.	EMMA Plan without satellite AWT plants; Nut I. expanded to 186 mgd	872.4	21.2	582.4
IIIB.	EMMA Plan with secondary treatment at satellite plants; satellite effluents discharged to Boston Harbor	846.5	22.7	581.2
IIIC.	EMMA Plan with secondary treatment at satellite plants; satellite effluents discharged to Charles and Neponset Rivers; eliminate Mother Brook diversion	810.0	22.5	563.0
IIID.	EMMA Plan with land treatment of satellite flows in middle Charles and upper Neponset areas; eliminate Mother Brook diversion	842.3	22.4	576.1
IIIE.	EMMA Plan with one satellite secondary plant (56 mgd) on Neponset River; effluent to Boston Harbor	843.2	22.3	575.8
IIIF.	EMMA Plan with one satellite secondary plant (56 mgd) discharging to the Neponset River; eliminate Mother Brook diversion	819.9	22.2	564.1
IIIG.	EMMA Plan with one satellite land treatment facility (56 mgd) on the Neponset River; eliminate Mother Brook diversion	853.4	22.4	582.7
IIIH.	EMMA Plan with one satellite AWT plant (56 mgd) on Neponset River; eliminate Mother Brook diversion	855.5	24.6	597.6
IIIJ.	EMMA Plan with primary treatment at Deer I. (400 mgd) and Nut I. (186 mgd); no satellite plants; effluents piped to ocean disposal	737.8	17.2	475.7
IIIK.	EMMA Plan with primary treatment at Deer I. (400 mgd) and Nut I. (186 mgd); no satellite plants; effluents discharged to present locations	581.5	15.4	390.9

No benefits were assumed for marginal water quality improvements. Benefits were considered to accrue only from an upgrading of water quality to a higher use class.

9.3 Alternative Investment Sequences

The Category I alternatives were arranged in various investment sequences to compare relative water quality benefits with the estimated costs of their achievement. Three such sequences are described in Table 9-4: the first sequence maximizes control of combined sewer overflows and urban stormwater in the present MSD service area; the second has the same objective for the expanded service area projected for the year 2000 by the EMMA study and the third sequence is the EMMA recommended detention/chlorination facilities for combined sewer overflows (ID.5), with the EMMA projected MSD service area expansion. All three investment sequences include the addition of secondary treatment (IE) for Deer and Nut Island effluents. Those water quality sections estimated to satisfy their recommended use class criteria as a result of each of the alternatives in each sequence are also listed in Table 9-4. A distinction was made in this assessment of acceptable water quality locations between those locations resulting from the Boston area NPDES required chlorination practice (and the disinfection effectiveness assumed in the Boston area for chlorination of primary or lesser treated effluents) and those locations which would be acceptable even without chlorination.

Boston area water quality benefits from each of the Category I investment sequences are compared with their respective costs, on a present worth basis, in Figures 9-2 and 9-3. The two maximum overflow and stormwater control sequences can be seen to result in both lower costs and far greater water quality benefits than the EMMA recommended overflow detention/chlorination facilities, with or without any assumptions about the propriety of chlorination. When the Boston area chlorination practice is discounted (Figure 9-3), this distinction becomes even clearer. Also, if chlorination is discounted, the addition of secondary treatment at Deer and Nut Islands can be seen to provide real and significant water quality benefits in Boston Harbor. The

TABLE 9-4

CATEGORY I INVESTMENT SEQUENCES

SEQUENCE 1: PRESENT MSD SERVICE AREA ONLY - MAXIMUM OVERFLOW AND STORMWATER POLLUTION CONTROL

Alternatives	Construction Completion Date	Acceptable Water Quality Sections With Chlorination	Acceptable Water Quality Sections Without Chlorination
IA.	6/84*	BH3-BH4	-
IB.	6/84*	BH3-BH4	-
ID.	6/84*	BH3-BH4	-
ID.2&4a	1/83	M4, BH1-BH4	M4
ID.2&4a,b	1/83	C7-C8, M4, BH1-BH4	C7-C8, M4
ID.2&4a-c	1/83	C7-C8, N2-N3, M4, BH1-BH4	C7-C8, N2-N3, M4
ID.2&4a-d	6/84	C1-C8, N1-N3, M4, BH1-BH4	C1-C8, N1-N3, M4
IE.1	5/85	C1-C8, N1-N3, M4, BH1-BH4	C1-C8, N1-N3, M4, BH1-BH4

SEQUENCE 2: EMMA PROJECTED MSD SERVICE AREA - MAXIMUM OVERFLOW AND STORMWATER POLLUTION CONTROL

Alternatives	Construction Completion Date	Acceptable Water Quality Sections With Chlorination	Acceptable Water Quality Sections Without Chlorination
IA.	6/84*	BH3-BH4	-
IB.	6/84*	BH3-BH4	-
IC.	6/84*	BH3-BH4	-
ID.	6/84*	BH3-BH4	-
ID.2&4a	1/83	M4, BH1-BH4	M4
ID.2&4a,b	1/83	C7-C8, M4, BH1-BH4	C7-C8, M4
ID.2&4a-c	1/83	C7-C8, N2-N3, M4, BH1-BH4	C7-C8, N2-N3, M4
ID.2&4a-d	6/84	C1-C8, N1-N3, M4, BH1-BH4	C1-C8, N1-N3, M4
IE.2	5/85	C1-C8, N1-N3, M4, BH4-BH4	C1-C8, N1-N3, M4, BH1-BH4

SEQUENCE 3: EMMA PROJECTED MSD SERVICE AREA - EMMA RECOMMENDED OVERFLOW DETENTION/CHLORINATION FACILITIES

Alternative	Construction Completion Date	Acceptable Water Quality Sections With Chlorination	Acceptable Water Quality Sections Without Chlorination
IA.	6/84*	BH3-BH4	-
IB.	6/84*	BH3-BH4	-
IC.	6/84*	BH3-BH4	-
ID.5	1/83, 12/85	BH1-BH4	-
IE.2	5/85	BH1-BH4	BH2-BH4

*Water quality sections BH3 and BH4 will be acceptable (with assumed effluent chlorination effectiveness) after present sludge discharge practice is discontinued according to EMMA schedule in April, 1980.

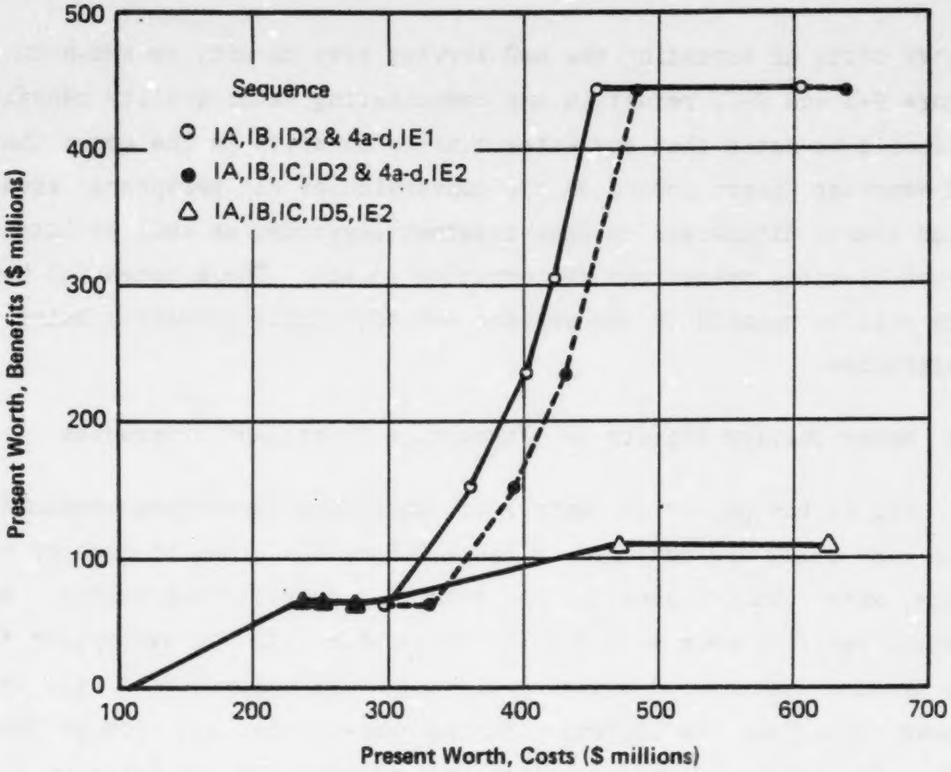

Figure 9-2 Category I Alternatives with Chlorination

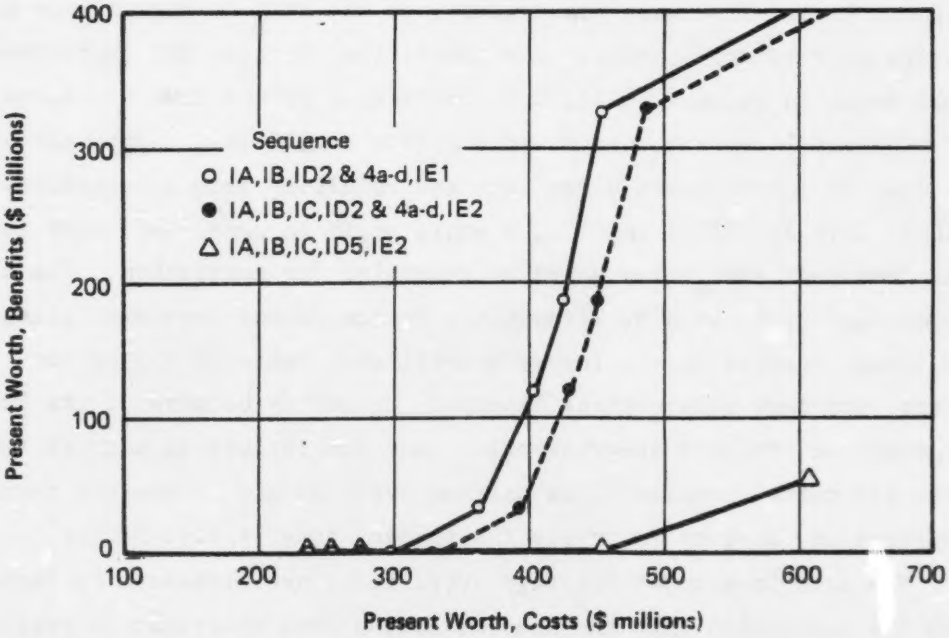

Figure 9-3 Category I Alternatives without Chlorination

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higher costs of expanding the MSD service area do not, as shown in Figure 9-2 and 9-3, result in any compensating water quality benefits. It should be noted that any water quality benefits in the upper Charles and Neponset Rivers depend on the conversion of all peripheral area point source discharges to land treatment systems, as well as intensive street cleaning operations (Alternative ID.4d). These potential benefits will be negated by the present AWT facilities presently being constructed.

9.4 Water Quality Impacts of Alternative Investment Strategies

All of the pollution control or investment strategies examined in this case study are compared in Table 9-5 on the bases of present value costs, water quality benefits and resulting benefit/cost ratios. Water quality benefits were estimated in this table with the assumption that the present Boston area practice of wastewater chlorination will be continued throughout the 20 year planning period, that is, through December, 2000. The timing of water quality improvements for the Category I alternatives have been described earlier. For all Category II and III alternatives, improvements in Boston Harbor sections BH3 and BH4 would begin in April, 1980 when construction of the EMMA primary sludge management facilities are scheduled for completion; section BH2 improvements would begin in January, 1983, upon completion of the EMMA Dorchester Bay and Neponset River combined sewer overflow facilities. Improvements in the Charles and Neponset River sections resulting from Alternatives IIID.2, IIID.3, IIIG.1 and IIIG.2 would begin in June, 1984 when satellite land treatment facilities would be scheduled for completion. The EMMA Recommended Plan, with or without the Boston Harbor treatment plant additions, results in the lowest benefit/cost ratio of any of the control strategy alternatives examined, primarily because of its inadequate treatment of combined sewer overflows and its failure to address the urban stormwater problem. The maximum overflow and stormwater control sequences in Category I provide the highest benefit/cost ratios.

The same investment strategy comparisons are presented in Table 9-6, with the assumption that the present Boston area chlorination practice will be either discontinued or its effectiveness discounted as better information about this practice becomes available within the next two

TABLE 9-5

WATER QUALITY BENEFIT/COST ANALYSIS OF ALTERNATIVE INVESTMENT STRATEGIES

				Conditions with Effluent Chlorination		
		Alternatives	Present Worth Costs ($ millions)	Acceptable Water Quality Sections	Present Worth Benefits ($ millions)	Benefit/Cost Ratio
Category I:		Sequence 1, A, B, D.2&4a-d	457.0	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.97
		with E.1, secondary treatment	607.1	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.73
I:		Sequence 2, A, B, C, D.2&4a-d	487.2	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.91
		with E.2, secondary treatment	641.4	C1-C8, N1-N3, M4, BH1-BH4	443.1	0.69
I:		Sequence 3, A, B, C, D.5 (EMMA)	454.3	BH1-BH4	107.2	0.24
		with E.2, secondary treatment	608.5	BH1-BH4	107.2	0.18
Category II:	A.	EMMA Recommended Plan	603.0	BH2-BH4	84.8	0.14
	B.	EMMA with STP additions	653.3	BH2-BH4	84.8	0.13
Category III:	A.	No satellite plants	582.4	BH2-BH4	84.8	0.15
	B.	Two secondary satellites, effl. to B.H.	581.2	BH2-BH4	84.8	0.15
	C.	Two secondary satellites, effl. to rivers	563.0	BH2-BH4	84.8	0.15
	D.1	Two land treatment satellites	576.1	BH2-BH4	84.8	0.15
	.2	with ID.4b-d, street cleaning	670.3	C1-C6, N2, N3, BH2-BH4	262.0	0.39
	.3	with land at upstream locations	670.3	C1-C6, N1-N3, BH2-BH4	283.8	0.42
	E.	One secondary satellite, effl. to B.H.	575.8	BH2-BH4	84.8	0.15
	F.	One secondary satellite, effl. to Nep.	564.1	BH2-BH4	84.8	0.15
	G.1	One land treatment satellite on Nep.	582.7	N3, BH2-BH4	108.3	0.19
	.2	with land at upstream location	582.7	N1-N3, BH2-BH4	163.9	0.28
	H.	One AWT satellite on Neponset River	597.6	BH2-BH4	84.8	0.14
	J.	Primary treatment, effl. to ocean	475.7	BH2-BH4	84.8	0.18
	K.	Primary treatment, effl. to Harbor	390.9	BH2-BH4	84.8	0.22

TABLE 9-6

WATER QUALITY BENEFIT/COST ANALYSIS OF ALTERNATIVE INVESTMENT STRATEGIES

		Alternatives	Present Worth Costs ($ millions)	Conditions without Chlorination Acceptable Water Quality Sections	Present Worth Benefits ($ millions)	Benefit/Cost Ratio
Category I:		Sequence 1, A, B, D.2&4a-d	457.0	C1-C8, N1-N3, M4	328.3	0.72
		with E.1, secondary treatment	607.1	C1-C8, N1-N3, M4, BH1-BH4	408.2	0.67
I:		Sequence 2, A, B, C, D.2&4a-d	487.2	C1-C8, N1-N3, M4	328.3	0.67
		with E.2, secondary treatment	641.4	C1-C8, N1-N3, M4, BH1-BH4	408.2	0.64
I:		Sequence 3, A, B, C, D.5 (EMMA)	454.3	None	0	0
		with E.2, secondary treatment	608.5	BH2-BH4	55.9	0.09
Category II;	A.	EMMA Recommended Plan	603.0	None	0	0
	B.	EMMA with STP additions	653.3	None	0	0
Category III:	A.	No satellite plants	582.4	None	0	0
	B.	Two secondary satellites, effl. to B.H.	581.2	None	0	0
	C.	Two secondary satellites, effl. to rivers	563.0	None	0	0
	D.1	Two land treatment satellites	576.1	None	0	0
	.2	with ID.4b-d, street cleaning	670.3	C1-C6, N2, N3	177.2	0.26
	.3	with land at upstream locations	670.3	C1-C6, N1-N3	199.0	0.30
	E.	One secondary satellite, effl. to B.H.	575.8	None	0	0
	F.	One secondary satellite, effl. to Nep.	564.1	None	0	0
	G.1	One land treatment satellite on Nep.	582.7	N3	23.5	0.04
	.2	with land at upstream location	582.7	N1-N3	79.0	0.14
	H.	One AWT satellite on Neponset River	597.6	None	0	0
	J.	Primary treatment, effl. to ocean	475.7	None	0	0
	K.	Primary treatment, effl. to Harbor	390.9	None	0	0

decades. The distinctions among alternatives become much sharper with the nonchlorination assumption. The EMMA-recommended Plan, as well as most of the Category III alternatives to EMMA, provide zero water quality benefits in the absence of chlorination or its assumed disinfection effectiveness. Only the Neponset River land treatment alternative, IIIG, would result in water quality benefits; adding Alternative ID.4b-d to Alternative IIID would provide additional benefits in the upper Charles River, but only if all upstream point source discharges were also converted to land treatment facilities. Boston Harbor sections BH3 and BH4 would become acceptable after secondary treatment, and even under Alternative IIIJ, if not for the fact that the EMMA wastewater flow projections result in no "treatment" of combined sewer overflows other than chlorination.

10. POLICY IMPLICATIONS

The implications of this analysis for water quality management policies are divided in this section into policies that are primarily engineering/scientific, administrative or legislative in nature. There is some arbitrary categorization in organizing this way, particularly in the divisions between engineering/scientific and administrative, where administrative policy changes could reasonably quickly alter engineering planning policies.

10.1 Engineering/Scientific

A recent series of case studies for EPA of the nation's planning process for advanced wastewater treatment concluded that "ignorance is the heart of the matter... planning is filled with assumptions, guesswork and oversimplifications because planners don't know nearly enough about water and the way it responds to wasteloads" (Horowitz and Bazel 1977). This ignorance of water and the way it behaves is illustrated by the EMMA study of metropolitan Boston. Despite a general recognition that combined sewer overflows and urban stormwater runoff are the major sources of pollution of Boston area waters, not a sample of either was collected or analyzed for the EMMA study. No effort was made to quantify either pollution source in the Boston area or to relate these sources in any predictive fashion to the specific water quality problems they cause. The EMMA planning decisions were seemingly not based on any water quality objectives or considerations, but on questionable estimates of sewage conveyance requirements. The EMMA planning alternatives were simply alternative sites, or combinations of sites, for a single preselected alternative: more and larger pipes, detention tanks and sewage treatment plants.

So long as the range of options is limited in this manner, there really is no place in the planning process for wastewater or water quality data, for any understanding of the complex cause and effect relationships between the two, or for any answers beyond larger pipes, tanks and treatment plants. Civil/sanitary engineering firms rationalize these limitations as dictated by conservative professional design practice; that is, it would be professionally irresponsible to risk a premature departure from established practice, from what has been done before. This "conservative" design concept has fair validity in civil engineering practice where public safety and public investments may be risked by failing or collapsing bridges, highways or other structures. The objective of water quality management, however, is not intrinsically a structure - it is clean, swimming/fishing quality water. Concern about the sewage treatment plant falling down need only arise when the appropriate response to the water quality objective is a sewage treatment plant. If building or enlarging the sewage treatment plant is an inappropriate response to the water quality objective - if it does not provide the best available insurance that the specified water quality criteria will be satisfied - then its recommendation is not "conservative" engineering practice within the professional context of the term.

A long series of reports and memoranda from the American Society of Civil Engineers' Urban Water Resources Research Program has for many years pointed up the failure of urban water resource planners to collect appropriate data. Instead, the general practice has been to substitute uncalibrated, unverified and far too elaborate mathematical models for the collection and analysis of necessary field data (McPherson and Mangan 1975; McPherson 1976).

The EMMA study's attempt to use the EPA's sophisticated Storm Water Management Model (SWMM) to describe the Boston area combined sewerage systems, in the absence of the detailed sewage flow and quality data necessary to calibrate this model, is an example of this practice. That the control options in SWMM are limited in practice to storage and treatment under a specific "design storm" condition is a further and serious problem with the use of this model in a water quality planning application.

10.2 Administrative

The analysis of the AWT* planning process referred to above (Horowitz and Bazel 1977) observed that: "In plain words, the Act (PL 92-500) requires the nation to plan like mad and build like crazy. And that, we fear, is exactly what has happened." The planning does in fact appear to be at least deficient and the building ill-founded, but that is not required by the Act; it is only the result of its administration. In its preoccupation with the wastewater treatment requirements of Section 301, Region I EPA has, in the Boston metropolitan area, understressed the one section of the Act that provides the basis for systematic and comprehensive water quality management planning - Section 303.

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*AWT planning was used by Horowitz and Bazel as a surrogate term for the entire water quality management planning process from which AWT, and also secondary treatment, plants emerged as the inadequate but expensive answer to undocumented and misunderstood water quality problems.

Section 303 spells out the essential series of steps that constitutes the water quality planning process. These steps are paraphrased as follows: (1) designate the uses of the state's navigable waters; (2) establish water quality criteria for these uses (steps 1 and 2 are to be subjected to public hearings at least once every three years); (3) identify those waters where water quality criteria will not be satisfied by the effluent limitations required by Section 301; (4) establish a priority ranking for such waters, accounting for the severity of their pollution and their proposed uses; (5) establish for such waters the allowable total maximum daily pollutant loads, at a level necessary to satisfy the applicable water quality criteria for the waters and (6) establish a continuing planning process that includes ... an inventory and priority ranking of needs for construction of waste treatment works* required to meet the applicable requirements of Section 301 (effluent limitations) and Section 302 (water quality related effluent limitations). An affirmative insistence upon rigorous compliance with all the provisions of Section 303, particularly upon the scientific adequacy of each compliance step, may present a technical and administrative challenge, but its importance to the water quality objective of PL 92-500 simply cannot be overstated. Without this insistence, that objective will not be achieved; with it, the EMMA Recommended Plan might never have assumed its present form.

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*"Treatment works" are generally defined in Section 212(2)(A) as "any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature to implement Section 201 of this Act...." Section 212(2)(B), however, substantially broadens this definition to include "any other method or system for preventing, abating, reducing, storing, treating, separating, or disposing of municipal waste, including stormwater runoff, or industrial waste, including waste in combined stormwater and sanitary sewer systems."

The straightforward implementation of recently proposed amendments to the EPA Cost Effectiveness Analysis Guidelines, published in Federal Register A2, 4 February 1977, No. 24, p. 6841, would minimize much wastewater planning indecision and, if this analysis of the EMMA study is an indication, save billions of dollars nationally in unnecessary treatment works expenditures. Wastewater flow projection limitations suggested here have been incorporated within the 1977 Clean Water Act (PL 95-217).

Several additional improvements in the cost-effectiveness analysis procedures are indicated. Pollution control alternatives involving water reuse, recycling, agricultural or silvicultural applications and best management practices are often too quickly and easily dismissed by construction-biased analysts. The cost-effectiveness analysis for infiltration* correction in combined sewer systems, for example, is incorrect. Correction costs seem typically to be compared with the apportioned costs of treatment of the additional flows which reach the existing treatment plant(s). The correction costs should be compared with the costs of wet-weather overflow control facilities which would be necessary to provide the same level of wet-weather pollution abatement, or with the costs of the additional sewerage necessary to make up for the existing wet-weather flow capacity occupied by infiltration. The scope of the cost-effectiveness analysis might productively be broadened to consider the costs and/or benefits to all environmental sectors. Agricultural and silvicultural applications, for example, and effectively managed on-site disposal systems, do represent some inherent land use and open space preservation options not offered by the conventionally recommended facilities. The intensive urban street cleaning operations examined in this case study would produce aesthetic and air quality benefits as well as those water quality benefits for which they would primarily be designed. The impact of large-scale regional sewerage systems, with uncontrolled I/I and extra-basin water transport, on the future water supply requirements of the region should be an appropriate consideration of a thorough cost-effectiveness analysis.

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*"Infiltration" for the purpose of this argument includes tidal inflow to the combined sewer system through malfunctioning tide gates, weirs, etc.

Regionalization of wastewater management ought to be seriously reassessed, if not actively discouraged, by EPA. The originally conceived benefits from regional economies of scale seem today to be more than offset by the costs of overdesigned or inappropriate facilities. Large end-of-the-pipe treatment facilities seem to be the only pollution control alternatives accessible to the regional "wholesaler." Otherwise acceptable solutions that might be manageable on a small local scale, for example, on-site disposal, land treatment and sewage collection systems operation, seem to become unmanageable at the larger regional scale. Regionalization has been advertised, in theory, as administratively simpler for EPA and the state regulatory agencies. EPA Region I's experience over the years with the MDC, and the water quality improvements resulting from that experience, suggests that the benefits of administrative streamlining are more than offset by the resulting system's loss of cost-effective opportunities.

It does not now appear very likely that more appropriate or cost-effective water quality management alternatives, such as those developed in the Boston case study, will be widely applied within the compliance schedules dictated by PL 92-500 without substantial federal encouragement. The combined sewer overflow and urban stormwater control alternatives developed in this study and elsewhere need to be demonstrated and compared by the federal government on a scale large enough to be accepted into the practice of conservative engineering and planning professions. The appropr[illegible] scale would require between $10 and $50 million for a five-year program designed to demonstrate, monitor, document and transfer technology for these alternatives. This is substantially beyond the present EPA research and development budget for storm and combined sewer overflow technology. The "Alternative and Innovative Technologies" provisions in PL 95-217, particularly the financial incentives and assurances, now provide the basis for demonstrations of the scale and timeliness suggested here.

The policy of chlorinating urban stormwater and combined sewer overflows, and other wastewaters as well, needs to be clarified. The EPA toxicity criteria and the NPDES requirements for chlorine residuals in Boston area combined sewer overflows are in direct conflict. The impact of large concentrations of chlorinated organic compounds on marine and fresh water biota could present hazards greater than those in drinking water supplies. Questions regarding this policy assume particular significance in light of the secondary treatment waiver provisions of the 1977 Clean Water Act (PL 95-217).

10.3 Legislative

The very serious flaws in the United States Clean Water Program are not so much in the law as in its administration. There are nevertheless a few additionally useful ammendments to PL 92-500 that could be considered. The massive public works spending effort that the EPA Construction Grants Program has become might be redirected toward something closer to the original objective of the Act if it were retitled "The Federal Water Quality Improvement Act." This would reemphasize the principal intent and concern of the Congress. The title of the Clean Water Act of 1977 does indeed reemphasize the intent of the Congress and may help to refocus the activities of the Administration on that intent.

The limitation of federal construction grants to a share of the project capital costs only should be seriously reconsidered. The result of this limitation seems to be the minimization of locally borne O&M costs through the selection of highly capital-intensive construction projects. Potentially less-costly and/or more effective (in terms of water quality benefits) alternatives are early screened out of the selection process because of their real or perceived excessive O&M costs. Correspondingly, little or no attention is given to the repair, operation and maintenance of existing systems, or to maximizing the performance of existing in-ground investments. A much broader spectrum of pollution control alternatives - perhaps some more effective, probably several more labor-intensive, certainly many less costly - would be encouraged if the federal and state cost sharing included participation in O&M costs also. A federal grant allocation system, revised to include annual O&M costs, might relatively easily be based upon a project's total present worth, computed as already specified in EPA's Cost-Effectiveness Analysis Guidelines (40 CFR, Part 35, Subpart E - Appendix A). Such a present worth-based grant allocation system would contain automatic financial penalties for missed deadlines and administrative delays. The longer into a specified planning period that a project was delayed, the lower its present worth (and federal subsidy) would become.

10.4 Public Accountability

The EMMA Recommended Plan is the culmination of a decade of major sewerage project construction in the Boston metropolitan area, to the apparent neglect of the water quality needs in the area. When fully implemented, the EMMA plan will have cost over a billion dollars and will have foreclosed for the remainder of this century any opportunity for swimmable/fishable waters in the Charles River, Neponset and Mystic Rivers and Boston Inner Harbor. There will continue to be no discernible accountability within either the local, state or federal agencies or the engineering community for the errors, misjudgments, and technical inadequacies that result in massive public costs with little or no significant water quality benefits.

11. EPILOGUE: AGENCY AND PUBLIC REVIEW AND COMMENTS

11.1 Introduction

Draft final reports of the federal interagency Boston Case Study were distributed on August 28, 1978 to Boston area governmental agencies and the public for review and comment. During the week of September 25-29, 1978, a series of meetings was held in Boston by the federal interagency study team and its contractors with various agencies and interested members of the public in order to elicit comments, suggestions for changes or corrections, and any questions regarding these reports. A public meeting, chaired by Dr. Evelyn F. Murphy, Secretary of the Massachusetts Executive Office of Environmental Affairs, was held at the John F. Kennedy Federal Office Building on September 27, 1978 to present study findings and agency responses and to hear public comments. Written comments were requested from interested agencies and persons. The written comments were distributed by the federal interagency study team among the four case study contractors for their consideration and response.

The original preface to the draft version of this report suggested that this study would be controversial. In view of the number and the nature of the comments it has evoked, that assessment was not entirely inaccurate. Because so many of the comments addressed similar concerns, or made nearly identical points, the preparation of an individual response to each of these comments or questions seemed redundant. Alternatively, comments have been grouped, where feasible, according to subject, reproduced verbatim, and responded to here by such groupings.

These groupings have necessitated the presentation of invididual comments in something other than the precise context in which they were originally submitted. It is hoped that these contextual sacrifices will be more than offset by the reinforcement and/or perspective provided each of the comments by their juxtaposition with others addressing the same topic. Each comment is attributed to a source; a complete list of the names and respective affiliations of individual commentators is included in Table 11-1.

TABLE 11-1

COMMENTATORS ON DRAFT STUDY REPORTS

Individual	Affiliation
Michael B. Cook	Acting Director, Facilities Requirements Division, U.S. EPA Headquarters
William R. Adams	Regional Administrator, EPA Region I
Rebecca Hanmer	Deputy Regional Administrator, EPA Region I
Daniel O'Brien	Municipal Facilities Branch, EPA Region I
William J. Butler	Water Planning Branch, EPA Region I
Allen J. Ikalainen	Systems Analysis Branch, EPA Region I
Wallace E. Stickney	Environmental Impact Office, EPA Region I
Fifi Nessen	Massachusetts Executive Office of Environmental Affairs
Martin Weiss	Chief Engineer, Metropolitan District Commission
Metcalf & Eddy, Inc.	Commenting for Metropolitan District Commission
Thomas C. McMahon	Director, Massachusetts Division of Water Pollution Control
Daniel P. McGillicuddy	Chief Planner, Massachusetts Department of Environmental Quality Engineering
Shirley M. Brown	Boston Harbor Citizens Advisory Committee
Herbert M. Meyer	Mystic River Watershed Association, Inc.
John E. Murphy	Boston Harbor Pollution Committee
W. Gary Williams	Clearwater Consultants, Inc.
Arthur Barnes	Norumbega Assocation
Howard Ris, Jr.	EPA Boston Harbor Pollution Advisory Committee
Lydia R. Goodhue	None
Margaret Hulls	None
Waldo H. Holcombe	Neponset Conservation Association

Three general comment groupings have evolved: (1) those concerning situational changes that have occurred since the study's completion and are unacknowledged in study reports; (2) those concerned with wastewater and water quality management policy issues; and (3) those concerned with specific technical analytical methods and assumptions of the study.

11.2 Situation Changes Since Case Study Completion

11.2.1 Misunderstanding of the Boston Area Planning Process

COMMENTS

A major focus of many of these criticisms concerns the failure of the case studies to adequately recognize the substantial wastewater management planning changes that have been made over the past two years in the Boston area. The errors and misstatements must be corrected, and all of the conclusions must be based upon sound analyses, if the final case study reports are to be presented as credible documents. I expect that you will make the necessary revisions. I recognize, of course, that for certain of our comments there may be honest differences of opinion and that all of the changes we recommend may not be made. In these instances, I request that our pertinent comments be included with the reports as appendix material. (Adams, EPA-I)

The Preface states that every significant element of the present Boston wastewater management plan is inadequate and will result in excessive costs and further degraded water quality. There are inadequacies in the water quality planning for the Boston area and the report does a good job of identifying these problems. However, it is unfair to imply that an EPA commitment to implementing the EMMA plan currently exists or that it represents the last word for pollution control facilities in the Boston area. Currently, an Environmental Impact Statement is studying satellite AWT alternatives and there are two infiltration/inflow studies being conducted. Moreover, a large grant will soon be made to analyze the combined sewer problem. This ongoing planning activity involves consideration of several alternatives, in addition to those recommended in the EMMA plan. Therefore, the Preface should be changed to more accurately reflect the existing situation. (Cook, EPA-HQ)

We are enclosing our previous comments on the draft report which should be considered in the final report. We especially note the need to change the Preface to accurately reflect current conditions. Facilities in the Boston area are still undergoing preliminary planning and there have been no funding commitments to construct any major wastewater treatment projects. Although some findings of the ERT study will serve as useful input to the ongoing studies, these findings will not serve to defer planning and design of major projects. (Cook, EPA-HQ)

We find innumerable problems with the OMB study. Its purpose, presentation and conclusions are neither clear or constructive. Its ramifications are clear; it adds to the confusion of an already difficult and complicated process. The general public can't help but be baffled by yet another study rather than a plan of action. The governmental manager at all levels is left with a sense of frustration, if not paralysis, by the absence of meaningful guidance in implementing the Clean Water program.

When the study began, MDC was told that its purpose was to improve the administration of the Federal Water Pollution Control Act using Metropolitan Boston as a case study. This suggests that a comprehensive evaluation of federal legislation, regulation, policies and programs was to be undertaken. We expected the study to produce a set of proposals for improving federal legislation and administration that would benefit the implementation of pollution control projects in metropolitan areas such as ours. Instead, the OMB study has resulted in four uncoordinated, unsuccessful, incomprehensible reports highly critical of all local efforts by federal, state, and metropolitan agencies. (Weiss, MDC)

The EMMA study, funded by the MDC and the U.S. Corps of Engineers and completed in 1976, was not intended to be a facilities plan. It was a comprehensive program for upgrading and improving the metropolitan sewerage system. As such it identified specific projects, treatment plants, combined sewer overflow control facilities, interceptors and pumping stations, for facilities planning. (Weiss, MDC)

The OMB study criticizes EPA's EIS because it was initiated prior to facilities planning and because it in fact tried to produce a facilities plan. Likewise the OMB study treats the EMMA study as a facilities plan and in effect attempts to suggest another facilities plan. It would be well if all interested parties allowed MDC to develop bona fide facilities plans, which would include preliminary engineering, environmental assessments and public participation as required by EPA, before blasting non existing facilities plans.
(Weiss, MDC)

In spite of its stated purpose as an evaluation of EPA's planning process, the study has not addressed that at all. In fact review of the EMMA Summary Report section entitled, "Next Steps" and "Status and Relationships of Other Related Programs," would have given the authors a better understanding of MDC's planning program relative to EPA planning requirements. (Metcalf & Eddy for MDC)

Our major criticism of this report is its total dependence on the EMMA report as a cast-in-stone solution rather than as a feasibility study. The report criticizes secondary treatment at the Deer and Nut Islands treatment facilities. A research study and modeling effort of Boston Harbor sponsored by this Division in 1974 showed that the primary treatment facilities did not have an adverse impact on the Harbor water quality. The Division has long been publicly against secondary treatment at these plants. The report fails to mention either of these facts. The report also fails to mention that the Division and EPA were required by law to include secondary treatment as a minimum in all municipal NPDES permits. (McMahon, DWPC)

The OMB study made no attempt to present the range of thinking and alternatives under consideration since the conclusion of the EMMA study. Further, it seems naive at best to suggest that such highly destructive reports were merely intended as observations rather than to influence the process. (Weiss, MDC)

There should be some acknowledgement of the reevaluation of the EMMA Plan that has or will take place (O'Brien, EPAI)

The case study entitled An Analysis of Water Quality Goals and Objectives in the Boston Metropolitan Area treats the old EMMA recommendations as if EPA and MDC were permanently committed to them. This conclusion must be challenged by EPA because, while the EMMA plan provided an initial framework for further planning efforts, those planning efforts have already caused changes.

The findings are based on the assumption that the EMMA Recommended Plan will be followed verbatim without any further study. This assumption is not at all representative of what has taken place and what will take place. This Agency will invest upwards of $10 million simply to re-evaluate and refine the recommendations of the EMMA Study. We have already given the MDC a grant for $3.5 million to study the combined sewer overflow problem in Greater Boston. An EIS that is being done by EPA on certain portions of the EMMA plan has come up with some preliminary recommendations that agree with certain recommendations of the Water Quality Goals and Objectives Report. For example, our preliminary conclusion on the issue of satellite plants is that they will not meet water quality standards and have therefore recommended against them. We are by no means blindly following the EMMA Plan. The EIS analyses predated receipt of the case study reports. (Hanmer, EPA-I)

(pg. 1-3)
Discussion here implies that the recommendations of the EMMA Study will be followed without further study. This is totally misleading. Major suggested revisions to the recommended plan have already taken place. The whole CSO control strategy is the subject of a recent $5 million facilities planning effort. (O'Brien, EPA-I)

(pg. 1-4)
We feel that the contractor's statement about foreclosure is a bit premature given the review of the EMMA Plan that is taking place and always was intended to be done. (O'Brien, EPA-I)

A major effort is underway to measure CSO quantity and quality as part of combined sewer overflow facilities planning.

The report discusses the EMMA CSO recommendations apparently without having read them. It ignores the relationship of facilities planning to the EMMA Study, as well as the fact that new standards have been developed for waters in this area.
(Metcalf & Eddy for MDC)

The EMMA Study briefly examined various alternatives for the control of combined sewer overflows, such as storage, sewer separation and solids removal. Cost estimates were presented on the alternatives of holding tanks with detention and chlorination facilities and it recommended further investigations during facilities planning.

The MDC began facilities planning for control of combined sewer overflows this summer under four separate consultant contracts - one each for Boston Inner Harbor, the Charles River Basin, Dorchester Bay, and the Neponset River Estuary. Under these contracts the consultants will be identifying and evaluating a range of structural and nonstructural alternatives and their impacts on water quality in Boston Harbor and its tributary rivers. The alternatives will be formulated after a thorough examination of the existing combined sewerage system, its flows and characteristics as well as further analysis of Boson Harbor water quality and its existing and potential uses.

The MDC as well as other agencies long ago recognized combined sewers as the single greatest source of pollution in Boston Harbor. To suggest for a moment, as the water quality report does, that MDC is unconcerned about water quality is irresponsible as well as erroneous. We need only point out that the bathing beaches of Boston Harbor, boating and sailing on the Charles River and sports fishing throughout are major recreational resources of the Metropolitan Boston under the jurisdiction of the MDC. We are confident that the facilities planning process now underway will result in a cost-effective solution for correcting the water quality problems associated with combined sewer overflows. (Weiss, MDC)

(pg. 7-7)
CSO control alternatives for the Boston area will be thoroughly investigated in a $5 million Facilities Planning effort that was initiated in June, 1978. The recommendations of the EMMA Study were only preliminary and will not be blindly followed.
(O'Brien, EPA I)

In May and early June of this year, over $3 million in EPA grants were awarded for combined sewer overflow facilities planning. The agency approved the grants after it was convinced that the scope of work: (1) covered all problem areas of Boston Harbor and the rivers flowing into it, (2) provided for a detailed characterization of problems experienced at each and every overflow point, and (3) examined all feasible options for combined sewer overflow control. The in-depth and large-scale facilities planning described in the scope of work, and which is now underway, will require approximately two years for completion. (Hanmer, EPA-I)

On page 1-4 it is stated that implementation of the EMMA plan will foreclose for the remainder of this century any opportunity for swimmable/fishable waters in the Charles, Mystic and Neponset Rivers and Boston Inner Harbor. ERT should have discussed the overall planning effort in the Harbor, not only the EMMA study. For example, the EMMA plan recommended satellite treatment on the Charles and Neponset Rivers to provide needed flow augmentation. Since the EMMA study, an EIS further evaluated these facilities and concluded that they would violate water quality standards in both streams. Therefore, the EIS recommended they not be built. In addition, as recommended by the EMMA study, detailed facility plans for the combined sewage systems are now underway. It is true that the EMMA study did not adequately evaluate the urban runoff problem. However, the 208 agency has begun to address the problem. They have inventoried storm drainage systems, conducted some sampling analyses of stormwater overflows, and have indicated further studies that will be needed to solve the urban runoff problem. Solving the urban runoff problem will determine when swimmable/fishable waters will be achieved. (Butler, EPA-I)

(pg. 1-24)
The EPA Draft EIS recommended against satellite plants due to their inability to meet Water Quality Standards. (O'Brien, EPA I)

The report states that the satellite plants will not improve the water quality in the Charles and Neponset Rivers. The Division's own analyses showed this to be true; however, this was not mentioned in the report. (McMahon, DWPC)

(pg. 8-3)
The examination of alternatives should include the all Deer Island proposal, recently recommended by EPA in the draft upgrading EIS. (Ris, BHPAC)

RESPONSE

There was, throughout much of this study and evidently thereafter, confusion about the exact legal planning status of the EMMA Recommended Plan. EMMA did not fit readily into any of the conventional planning categories specified by Sections 201, 208, or 303 of PL92-500, nor was it originally intended to do so since its initiation predated the Act. It is described by the SWPC, above, as a feasibility study and by EPA Region I as an initial framework for further planning efforts. The MDC calls it a comprehensive program for upgrading and improving the metropolitan sewerage system. EPA, at all levels, strongly contends that no straightforward or automatic commitment to the EMMA Recommended Plan has ever existed. Nevertheless, major recommendations of the EMMA Plan have been adopted in an agreement between MDC and MAPC a part of the the Boston Area 208 plan. Furthermore, the EMMA Plan has been accepted by EPA-Region I as the 303(e) Water Quality Management Plan for Boston Harbor and its tributaries. Literature describing this plan and the implementation schedule of its 10 major construction projects was distributed publicly by the MDC as recently as September 26, 1978.

The EMMA Plan was not treated in this study as a facilities plan; it was treated as the only available plan in existence during the period of the study. That so many of its assumptions and recommendations have subsequently been questioned or rejected should reinforce the conclusions resulting from this study about the probable water quality impacts if the plan were implemented.

The EIS recommendation against satellite plants is well advised. If the EMMA Plan had been based on water quality requirements, they would perhaps not have been proposed in the first place. The all Deer Island Plan recommended in the EIS would, incidentally, not be different in terms of water quality conclusions from Alternative III-A presented in the Boston Case Study. Total wastewater flow, level of treatment, and discharge location for the single treatment plant were not projected in the EIS to be effectively different from the two plants considered in Alternative III-A.

It is encouraging that the facilities planning for CSO controls is being expanded beyond the limited alternatives examined in the EMMA Study. One of the serious difficulties with this study was that, while "the MDC as well as other agencies long ago recognized combined sewers as the single greatest source of pollution in Boston Harbor," "the EMMA study [only] briefly examined various alternatives for the control of combined sewer overflows." It should be noted, however, that the distribution of individual facilities planning contracts does not seem to encourage area-wide solutions or the basin-wide coordination that would be required, for example, to automatically flush, store in-line, and selectively route flows in combined sewer systems. The present examination by EPA Region I of sewer flushing as a CSO control alternative, as suggested by this study, is to be encouraged. It should be of interest to Region I EPA that the draft 1978 Needs Survey for Control of Combined

Sewer Overflow and Stormwater Discharge relies strongly on sewer flushing and street cleaning as the most cost-effective first steps toward control of these pollution sources.

11.2.2 Revised Water Quality Standards

COMMENTS

The report is critical of the Division's Water Quality Standards, however, new standards, which incorporate many of the revisions suggested by the report, were adopted during the summer of 1978. The report also states that the satellite plants will not improve water quality in the Charles and Neponset Rivers. The recently published EIS on the EMMA Study also recommends not building the plants, and additional studies performed by this Division also support this conclusion. (McMahon, DWPC)

(pg. 3-16)
We would just like to note that the State Water Quality Standards were in the process of revision at the time of report preparation. The contractor was aware of this process, but failed to acknowledge it in the report. The "recommended" criteria developed by the contractor are in many ways similar to the revised state standards. (O'Brien EPA-I)

The report cites several deficiencies in the establishment of water quality standards by DWPC. The revised standards promulgated in the past year should be reviewed to determine if the deficiencies have been corrected. Why was enforcement action never taken by EPA to correct the problems identified prior to this time? (Ris, BHPAC)

On page X the report states that "in 1974 the criteria for dissolved oxygen, nutrients and bacteria, precisely the quality parameters of most concern for Boston area waters, were either relaxed or effectively removed from the Massachusetts standards." This statement is false. In 1974, Massachusetts did remove the numerical limits for nutrients because they could not be supported scientifically. The state now relies on a narrative statement for all waters and point source discharge prohibition of nutrients to lakes to protect its waters from excessive algae-criteria for dissolved oxygen and bacteria were not relaxed in 1974. Further, major revisions to water quality standards have been made by Massachusetts in 1978. The ERT consultant who was aware of the proposed revisions in 1977 should have acknowledged them. Many of ERT's recommendations for revisions to the water quality standards were the same as Massachusetts had proposed in 1977 and adopted in 1978. (Butler, EPA-I)

The Water Quality Report presents inaccurate, frightening and unsubstantiated changes. It criticizes the state's water quality standards but fails to acknowledge that they were in process of revision when their report was being drafted. In fact, the new state water quality standards significantly increases the dissolved oxygen parameter for Boston Harbor. (Weiss, MDC)

(pg. 3-31)
The revised state standards utilize the MPN criteria in marine waters. The revised standards no longer have the coliform exception noted here. (O'Brien, EPA-I)

RESPONSE

It is true that the Massachusetts Water Quality Standards were revised in 1978 and also that the author of this report was aware of (and perhaps participated informally in) the revision process underway during 1977. This process, and its progress, are acknowledged on page 3-2 of this report. It might be debated, at this point, whether the revisions finally adopted should fairly be described as "major," or more precisely, whether "major" in this case is synonymous with "improved."

The drinking water criteria recommended in this report for total dissolved solids, chlorides, sulfates, and nitrates are now included in the 1978 Criteria for Class A Waters. The category "Other Chemical Constituents" are now referenced to the EPA publication Quality Criteria for Water (EPA-440/9-76-023) as suggested by this report. The criteria for radioactivity are updated to EPA National Drinking Water Regulations. The criteria, however, do not include Protection Guides for direct consumption of aquatic and marine organisms, as recommended in this report. The criteria for "tainting substances" have been added, as recommended in this report. The quite erroneous 1974 language describing the temperature criteria for fresh waters has been corrected, as recommended in this report. The 1978 criteria for temperature in marine waters, however, are the same tautological narratives that existed in 1974. The 15 mg/l oil and grease concentration criterion has been corrected to a 15 mg/l discharge limitation. This, of course, continues to confuse water quality criteria with effluent limitations, although to a lesser degree for this parameter than did the 1974 criterion. The 1978 pH criteria for Class A and B waters remains the same as the 1974 criteria. The

Class C criterion for pH has shifted upwards one-half unit, from the 1974 range of 6.0 to 8.5 to the range 6.5 to 9.0 in 1978. The pH criteria for Classes SA and SB marine waters have been relaxed from the 1974 range of 6.8 to 8.5 to the Class SC criterion of 6.5 to 8.5 in 1978. There have been no effective changes from the tautological narratives used as criteria for color and turbidity and for nutrients; the nutrient criterion, however, now seems to apply to all the waters of the Commonwealth rather than to lakes, ponds, and their tributaries only.

The criteria for DO have been improved. The language describing limits based on percent of saturation and minimum hours of the day has been replaced with much simpler, more straightforward language. Also, the B1 and C1 water use classes have disappeared from the 1978 standards. Numerically, the 1978 Class A and B criteria for dissolved oxygen are the same as in 1974; the 3 mg/l minimum for warm water fisheries has been increased to 5 mg/l. A minimum of 6 mg/l has been adopted as the dissolved oxygen criterion for all marine waters classes. This, as noted in comments above, is a more stringent criterion for SB and SC waters than those in the 1974 standards. It is, however, a one-half unit relaxation of the criterion for Class SA waters, which was 6.5 mg/l in 1974. It should be noted that no scientific foundation was found during this study, or since, for a marine waters dissolved oxygen criterion more stringent than about 5 mg/l.

A very major difficulty with the 1978 standards is the criteria for coliform bacteria, which do not appear to have been reviewed for statistical conformity. With the exception of Class SA waters, the 1974 criteria for total coliform bacteria were based on average values. The language in the 1974 standards, furthermore, was sufficiently ambiguous to permit these averages (medians for Class SA) to be interpreted as monthly averages. This interpretation provided the necessary flexibility to include the random variations associated with rainfall events, while still providing defensible planning criteria for management of water quality and control of pollution during and after those events. The criteria for coliform bacteria recommended in this report were designed specifically to remove the ambiguity and to clarify this latter interpretation. The 1978 Massachusetts criteria for coliforms (some are total, some are fecal) are now more inconsistent than before. The criteria for all fresh water classes will be significantly more severe, because it now seems clear that the criteria are to be applied to *each set of samples*, as well as to the total number of monthly samples. As a statistical aside, it apparently needs to be restated that a log mean (the 1978 criterion) cannot be computed for a sample set containing either zero or too many to count (TMC) values. The more correct probabilistic determinant of a sample set is its median. The 1978 coliform criteria for marine waters have all been converted to most probable number (MPN) values, which typically result in somewhat higher numbers of organisms for a given sample of sea water than the Millipore filter (MF) values used in the 1974 criteria. Numerically, the 1978 Class SA criterion is identical to the 1974 criterion, although the specification of MPN values would effectively reduce the allowable coliform concentrations for this class, making the 1978 criterion more severe. Both the 1978 and 1974 criteria were based on median values. The 1978 Class SB criterion has been effectively *relaxed* from the 1974 criterion by specifying *median* instead of the 1974 *average* values. Medians of small numbers of bacterial samples typically will be significantly smaller than averages. The ambiguity of the 1978 language for Classes SA and SB still allows the interpretation of applicability to include *all* monthly samples. The Class SC criterion, however, returns to the language of the fresh water Class C criterion for fecal coliforms and specifies log means for *a set of samples*, rather than the *average during any monthly sampling period* specified in the 1974 criteria for Class C and SC waters. It may, in fact, be more difficult for the same body of water to satisfy the SC fecal coliform criterion than the SB total coliform criterion. A clear improvement to be noted is the elimination in the 1978 criteria of the relaxed bacterial limits for Class C and SC waters subject to urban runoff or combined sewer discharges. In summary: the coliform criterion for Class SA waters is *more severe* in 1978 than in 1974; the coliform criterion for Class SB waters is less severe in 1978 than in 1974; the 1978 coliform criteria for all other classes is either more severe (because of clear application to every sample set) or less severe (because log means will be consistently less than averages) than the 1974 criteria, depending entirely on the interpretation of the 1974 criteria that is accepted. The 1978 definitions (Regulation 1.5) for "pollutant" and "discharge," coupled with Regulation 2.1, Establishment of Effluent Limitations, seem relatively easy to construe as a requirement that all municipal stormwater discharges and combined sewer overflows must provide a minimum of secondary treatment (primary treatment plus disinfection for discharges to coastal and marine waters).

By way of acknowledging the use classification improvements in the 1978 standards, it is noted here that the 1974 C classification segments upstream from the Watertown Dam in the Charles River, the Mystic River from the Lower Mystic Lake outlet to the Amelia Earhart Dam, and upstream from the Milton Lower Falls Dam in the Neponset River, were all upgraded to Class B waters in 1978.

11.2.3 Erroneous Water Quality Predictions

COMMENT

(pg. 1-2)
Last paragraph - first sentence - Comment on water quality and fishing is not entirely accurate. Fishing occurs on the Charles River above the Watertown Dam to the source of the river. Warm water fisheries (bass, pout, etc. are caught and fishing is active). Information comes from observations along the river and discussions with people who fish the river. (Ikalainen, EPA-I)

RESPONSE

Fishing also occurs in the Charles River Basin below the Watertown Dam, but that does not make the basin any less polluted. Swimming also occurs from time to time at some places in the upstream Charles and in the Mystic Lakes. The point is that the Massachusetts water quality criteria for these activities is violated at all but the two locations cited in the Boston metropolitan area case study.

COMMENT

Under number 4 (Kennedy Engineers' report, Ch. 5, page 91) please list the beaches that have been permanently closed and the approximate date of closure. (O'Brien EPA-I)

RESPONSE

There have been at least five beaches permanently closed in the Charles River Basin alone, including Havey Beach, Charlesbank Beach, and Magazine Beach, the latter having been closed in 1959. Throughout the Boston metropolitan area, the beaches now closed would number close to a hundred; their detailed listing is beyond the scope of this report.

COMMENTS

Another prediction by the case study drafters that led to the statements on water quality degradation was that an EPA-funded destratification project on the Charles River Basin would cause severe hydrogen sulfide (odor) problems and resuspend toxic pollutants throughout the basin. This project has been in operation a few months, and we are pleased to report that except for on the first day of operation the hydrogen sulfide levels have been below detectable limits. The dissolved oxygen, which once was zero, is now 5 mg/l on a consistent basis. This level of D.O. is capable of supporting a diverse population of fish. Measurements of turbidity and plankton have not shown significant increases. (Hanmer, EPA-I)

(pg. 1-28)
The contractor's predictions about the destratification program do not correlate with the early monitoring results of this project which show increased D.O. levels, no hydrogen sulfide problems and little increase in turbidity. (O'Brien, EPA-I)

On page 1-28, it is said that "detention-chlorination facilities, combined with an EPA-finanaced MDC destratification project in the Charles River Basin, will have a result heretofore not believed possible. They will result in even poorer quality water in the Basin than there is at present." This statement is not true. The combined sewer abatement projects will greatly reduce the overflows of untreated combined sewage and the destratification project has been operating successfully for several months, including the warm summer months. (Butler, EPA-I)

As an example, the Charles River Basin destratification project is projected to result in the release of large amounts of hydrogen sulfide gas. The project has been in operation for a number of months and the predicted problems have not occurred. (Butler, EPA-I)

RESPONSE

It should probably be noted that water quality in the Charles River Basin is a function of streamflow. At very low flows, the salt wedge on the bottom of the Basin moves further upstream and also rises nearer to the surface. Detention time increases, as do hydrogen sulfide concentrations in the bottom saline layer; algal populations and dissolved oxygen in the surface layer increase. Conversely, at higher flows there is greater dilution in the surface layer, the bottom salt wedge layer decreases in volume, moves back downstream, and recedes from the surface. Upstream of the Longfellow Bridge, this saline bottom layer is constrained from dropping much lower than about 10 feet below the Basin surface because of a 10 to 15 foot high underwater barrier beneath the Longfellow Bridge and extending the width of the Basin. Because of this barrier, the stratification is relatively stable in that part of the Basin upstream of the Longfellow Bridge.

Downstream of this bridge, however, there is considerable exchange of freshwater and seawater through the locks of the Science Museum Dam, and the stratification is always much less pronounced. FWPCA measurements at the Longfellow Bridge (5-foot sampling depth) indicated that dissolved oxygen averaged 5.6 mg/l in July and August 1967, with a minimum of 3.6 and a maximum of 9.6 mg/l. Streamflow during this period at the Charles River Village gage ranged from a low of 89 cfs (August 2) to 215 cfs (August 7). Massachusetts DWPC data from June 1974 show that DO in the portion of the Charles River Basin downstream of the Longfellow Bridge did not approach zero at any sampling location or depth. The average DO at a 4-foot depth was 8.8 mg/l, with a minimum of 6.3 mg/l; average DO at 18 feet was 2.4 mg/l with a minimum of 1.0 mg/l. Dissolved oxygen in the bottom waters upstream of the Longfellow Bridge were consistently at or near zero. Streamflow at Waltham during the June sampling period averaged 200 cfs (minimum 190 cfs). DWPC data from August 1974, when streamflow at Waltham averaged 34 cfs, indicated that the average DO below the Longfellow Bridge was 3.3 mg/l at the bottom (13 to 16 feet) and 9.3 mg/l at a depth of 4 feet. It might be instructive to note that the minimum streamflow at Charles River Village during the summer of 1978 was 36 cfs on July 31, and that streamflow was as high as 687 cfs on August 12, 1978.

Of probably greater relevance to the criticisms of water quality predictions in this report, however, is the fact that the Charles River Basin destratification project is not now, nor was it during the summer of 1978, in actual operation. The destratification equipment consists of a total of six aerators installed in the Basin: one between the Science Museum Dam and the New Warren Avenue Dam; two between the Science Museum Dam and the Longfellow Bridge; two between the Longfellow Bridge and the Harvard Bridge; and one upstream of the Harvard Bridge. The two aerators just downstream of the Longfellow Bridge were turned on about May 1, 1978. Summertime DO levels of 5 mg/l are not particularly unique in this area and H_2S problems would be surprising. The stable stratified layers and the bottom layer hydrogen sulfide accumulations exist upstream of the Longfellow Bridge. None of the aerators in this area were in operation during the summer of 1978, or since.

11.2.4 PL95-217 and Other Changes

COMMENTS

(pg. 10-4)
The discussion of regionalization should be updated to include an analysis of how the Clean Water Act Amendments will or will not encourage decentralized, non-structural pollution control.
(Ris, BHPAC)

The report fails to note (even in some sort of introductory paragraph) that significant changes have been brought about by the passage of PL 95-217. (McGillicuddy, DEQE)

To the extent that the report suggests and contributes to improved water quality studies and evaluations we are in support of many of the recommended items. (Butler, EPA-I)

The report sets forth numerous conclusions and recommendations for which there are not any substantive analytical backup. Many points are based upon subjective judgments and assumptions which cannot be scientifically supported or rejected. The report does not acknowledge that numerous aspects of the report are currently in developmental stages. (Butler, EPA-I)

In summary the ERT report discusses some important issues that need to be addressed to improve Boston Harbor water quality. Most of these issues are being evaluated since the publication of the EMMA report. Because the report was not up-to-date and contained many errors and personal biases, it is of little value in influencing issues of national and regional importance. (Butler, EPA-I)

As a final comment, it is my opinion that planning for effective wastewater management in the Boston metropolitan area is now underway. Where necessary, the conclusions and recommendations of past plans are being amended and improved. This is a natural consequence of the facilities planning and environmental impact statement preparation processes that have been, and will be conducted. I am confident that cost-effective solutions will be expeditiously implemented for the water pollution problems that now affect Boston Harbor and its tributaries. (Adams, EPA-I)

RESPONSE

The impact of the Clean Water Act of 1977 (PL 95-217), enacted since the completion of the Boston Case Study, can be assessed as a mixed bag. The naming of the Act was certainly consistent with one of the legislative policy suggestions included in this report. The alternative and innovative technologies provisions of the Act should encourage further exploration and demonstration of the kinds of alternatives suggested in this report. Locally preferable pollution control alternatives, on-site disposal options, etc., should also be encouraged, as they have recently been by a number of PRM's from EPA Headquarters. On the other hand, federal participation in the costs of controlling pollution from separate stormwater discharges has been discontinued and this is a serious source of water quality degradation in the Boston metropolitan area. The provision for possible waivers of the secondary treatment requirement for coastal communities, Section 301(h) of the Act, will in all likelihood further delay the achievement of acceptable water quality in the Boston area and probably elsewhere. This provision of the Act may turn out to have been ill-advised.

While acknowledging the changes that have occurred since the completion date of this study, it might also be useful to summarize the significant changes that have not occurred, as of January 1979:

1) The Charles River Basin use classification is still Class C; the Mystic River below the Amelia Earhart Dam and the Boston Inner Harbor are still classified SC; the Boston area 303(d) segmentation still erroneously classifies the Charles River Basin and all of Boston Harbor as "Effluent Limited."

2) The EMMA Study, though virtually every significant facility it proposed is being questioned or rejected, is still the 303(e) Water Quality Management Plan for Boston Harbor and its principal tributaries; maximum allowable daily pollutant loadings have not been established for these waters.

3) There is still no urban stormwater management plan for the Boston Metropolitan Area.

4) Massachusetts Water Quality Standards remain flawed, although in some instances for different reasons now than in 1974; they now appear, for some parameters, more stringent than is scientifically defensible as well as not likely to be literally implementable.

5) Another year has passed with no water quality improvements in the Boston Metropolitan Area.

If there is any single important conclusion to be drawn from this study of water quality goals and objectives it is the following:

> Unless and until any revised or new plan takes into explicit account these necessary requirements of swimming/fishing quality waters - in fact, until quantitative and specific water quality requirements are adopted as the fundamental, uncompromised planning criteria themselves - any new plans are not likely to be any more environmentally productive, or less wasteful of public finances, than the original EMMA Plan.

11.3 Policy Considerations

11.3.1 Water Quality Management Planning

COMMENT

(pg. 3-6)
The assumption that EMMA was approved due to concern for federal financing eligibility is unfounded. It is unclear what eligibility was supposedly of concern, i.e., funding of the EMMA report itself or funding of its recommended plan. (O'Brien, EPA-I)

RESPONSE

Section 204(a) of PL 92-500 requires that, before approving grants for any project for any treatment works under Section 201(g)(1), the Administration shall determine that such works are in conformity with any applicable State plan under Section 303(e) of this Act.

COMMENT

On page XI, ERT indicates that the EMMA plan substituted unspecified treatment technology limitations for combined sewage abatement instead of developing waste load allocations for critical pollutants. It is true that specific waste loads were not developed for combined sewage discharges and nonpoint sources. In general the majority of Phase I basin plans around the country did not adequately evaluate these sources of pollution. The 208 water quality management planning and state Phase II basin planning efforts are beginning to address these complex waste sources. The EMMA plan based its combined sewage recommendations on the assumption that there shall be no raw overflows based on a one-year frequency rainfall and that chlorination-detention facilities would be a likely receiver of the collected combined sewage. The discharge from these facilities would be to waters of low recreation potential because of physical limitations. The EMMA plan did recommend detailed facilities plans be prepared to more fully evaluate combined sewage abatement to the Harbor's recreational waters which will produce significant water quality benefits. (Butler, EPA-I)

RESPONSE

This report, and obviously the Boston Metropolitan Area population, does not agree that the Charles River Basin, Dorchester Bay, etc., are waters of low recreation potential.

COMMENT

The findings imply that the EMMA Plan in and of itself will prevent water quality standards from being met. We feel that this is an unfair representation. It one reads beyond the EMMA Reports' Executive Summary, one will find that the point being made is that unless urban runoff is controlled, standards will continue to be violated. The impact of urban runoff is a recently-emerging National issue that requires a lot more research. However, we believe that provision for secondary treatment of dry weather flows and effective control of combined sewer overflows will bring significant reductions in the current pollutant loadings. We believe that these controls are a necessary component of any overall water quality management plan. (Hanmer, EPA-I)

RESPONSE

The EMMA Recommended Plan, with or without the Boston Harbor treatment plant additions, results in the lowest benefit/cost ratio of any of the control alternatives examined, *primarily because of its inadequate treatment of combined sewer overflows* and its failure to address the urban stormwater problem (emphasis added). See page 9-12.

COMMENT

On page 1-13, ERT states that Massachusetts has not complied with Section 303(c) of Public Law 92-500. Section 303(c) requires each state to review its standards and hold a public hearing at least once during each three-year period. Massachusetts has complied with this requirement. (Butler, EPA-I)

RESPONSE

More precisely, page 1-13 states: "The classifications shown in Figure 1-1 [Boston Harbor] were established in 1967 and, contrary to the requirements of Section 303(c) that applicable water quality standards be reviewed in public hearings at least once in each three-year period beginning with the date of enactment of PL 92-500, *these classifications have not been reviewed since*" (emphasis added).

COMMENT

(pg.9-1)
The statement that prior to 1977 available funding exceeded available projects is incorrect. Massachusetts has always obligated its' total annual allotment. (O'Brien, EPA-I)

RESPONSE

This comment is technically correct. Massachusetts does seem to have always obligated its' total annual allotment. The doing so, however, has required the financing of a great many projects having little contribution to correcting the major pollution problems of the Commonwealth. The apparent desperation to somehow obligate these allotments was evidenced by Region I EPA's series of local television commercials requesting citizens to call or write their town councilmen and mayors and urge their applications for these funds while they were available. The text of this report, nevertheless, has been changed to read "available high priority projects."

COMMENT

We do not agree that "class violation" is the only parameter associated with water use. We feel that all eight parameters have either a direct or indirect impact. We do not see how the contractor concluded that such parameters as coliform, color or temperatures have no effect on water use. (O'Brien, EPA-I)

RESPONSE

Certainly water quality will have an effect on water use. Water quality or water quality parameters, however, are not measures of water use and certainly are not measures of the uses to be made of such waters. The interpretation indicated in this comment ignores the seemingly clear legislative intent of Section 303(d).

COMMENTS

(Executive Summary)
The report states: "No evidence was found in the Boston area of a serious concern about either compliance with or enforcement of Section 303." Why has this occurred? (Ris, BHPAC)

(pg 3-6)
The report cites major flaws in EPA's acceptance of the EMMA study as the 303 water quality management plan for the metropolitan area, since it deals with wastewater management instead. What steps can be taken to rectify this situation? Are 303 plans prepared for other regions of the state any better? (Ris, BHPAC)

(pp. 10-2 - 10-3)
The report's conclusion that the basis of systematic and comprehensive water quality management planning lies in compliance with the requirements of Section 303 is well advised. However, it would be instructive if the researchers had probed farther into why the 303 system has failed, and what specifically could be done to improve its effectiveness. Similarly, they cite lack of water quality data as a principal problem, but do not address the reasons why such data was never collected. If it is a matter of cost, the report should recommend that more funding be targeted in this area. (Ris, BHPAC)

RESPONSE

Compliance with Section 303, particularly the establishing of total maximum daily pollutant loads and then implementing a management process based upon those loads, seems generally to involve professionally difficult judgements and politically painful decisions. Not enough data is likely ever to exist to prove to all parties the validity of the predictive models necessary for estimating allowable daily pollutant loads and, once established, these loads need to be apportioned among competing interests with varying degrees of political influence. Section 301 is clearly simpler to administer than Sections 302 and 303. Nevertheless, water quality improvement in the Boston Metropolitan Area will not likely be achieved without systematic and conscientious compliance with the provisions of Section 303.

COMMENTS

E.P.A.----BOSTON HARBOR CITIZENS ADVISORY COMMITTEE

SUBCOMMITTEE REPORT----AIR AND WATER QUALITY

The intent and purpose of this report is to derive a procedure to obtain the highest quality of clean air and pure water, as is possible, by locating the sources of the contamination of the Air and the Water, in the Boston Harbor Area, and suggesting the means that can be pursued to eliminate the sources of the pollution.

Quincy Bay Area, Nut Island Sewage Plant.

The outflow from the Nut Island Plant is a great contributing source of pollution of the water, under normal operating conditions and, also, due to break-downs and malfunctioning of the plant.

The first corrective measure is to provide adequate routine servicing and preventive maintenance to eliminate operating failures.

The long range plan of development is to control the outflow by constructing pipeline and/or tunnel to carry this waste out to deep water, three to five miles beyond Graves Light, to be combined with the outflow from Deer Island Sewage Plant, where it can be readily ingested in the greater area of deeper water.

Winthrop Area, Deer Island Sewage Plant

The tremendous amount of outflow from this plant into Boston Harbor daily, 415 million gallons, or more, certainly cannot continue without grave consequences to human health and the contamination of marine matter and gill fish and shellfish.

Secondary sewage plants will not be the answer to clean water, they may ameliorate the condition but not eliminate the contamination.

The outflow from the Deer Island must be piped or tunnelled out to deeper water and combined with the outflow from the Nut Island Plant to accomplish what is humanly desired and required in order to obtain the objective of clean water in Boston Harbor; otherwise the beaches, both on the mainland and the Islands, will be destroyed, swimming as a sport and recreation will not be available in the Boston Harbor Area.

Boston Harbor is a congested area because of its many islands, the ebb of the tide does not carry the sewage out-flow out into the ocean, thereby causing the flow of the tide to carry the pollution back into the Harbor.

Let me quote a distinguished person on this particular point.

> "Organic nutrients resulting from the discharge of either primary or secondary effluent should not be released in any semienclosed body of water such as Boston Harbor or Quincy Bay in which the nutrients concentrations can increase to the point of using up the normally existing dissolved oxygen content of the water."

Boston Harbor Drainage Area

Other Sources of Sewage into Boston Harbor

There is occasional and periodical permission of sewage discharge into Boston Harbor (Dorchester Bay) from the Pumping Station at Columbia Point.

This discharge, however slight or often, should not be allowed to continue. Clean water and the health of the people should and must be the first consideration.

Whatever reason there may be for the discharge from this plant must be thoroughly surveyed and corrective measures taken to control the sewage at this location to eliminate the discharge.

Combined sewage overflow storm drain water runoff and industrial outflows into Boston Harbor contribute, to a great extent, to the constant pollution of the shorelines in many sections of the Harbor.

Steps should be taken to get at these sources and remedies made to correct the damaging influence of these sources of pollution.

Tide gates, several of these are located in and around the shores of Boston Harbor and it is known that many of these are in very bad operating condition. Because of faulty operating conditions seawater flows back into the sewage system causing damage to equipment often resulting in breakdowns.

It would seem that it is imperative that tide gates should be eliminated from the sewage system without any further delay, for one who has observed the outflow from some of the tide gates no time should be further delayed in rerouting the sewage from these gates into the mainstream of the sewage system. (Murphy, BHCAC)

My testimony is based on an appeal to you to think of sewage as a potential public asset and to think of the unique characteristics of our harbor, the Deer and Nut Islands sewerage systems and the MDC Sewerage District communities which they are designed to serve.

I will suggest that secondary treatment, with the proposed drying and burning of sludge, NOT be pursued. And that instead there be instituted three interrelated projects:

1) upgraded primary treatment procedures for both effluent and sludge.

2) extension of outfall pipes to a point at least six miles off Deer Island.

3) reconstitution of a dilute slurry from the separately treated effluent and sludge, so that the resulting single "homogenized" discharge can be pumped and dispersed continuously with minimization of the tendency of sludge to build up on the harbor bottom.

In making these proposals, I assume that there will be continued progress on several related projects:

a) separation of storm and sanitary sewers in the MDC Sewerage District.

b) interception and treatment of industrial wastes, heavy metals, nonbiodegradable organics, etc. at their source.

c) minimization of point sources of pollution that affect the harbor.

d) upgrading of primary treatment to increase control and reliability.

e) upgrading of treatment of sludge to minimize toxic characteristics. (Barnes, EMMA CAC)

While I was a member of Marblehead's Sewer Study Committee, it was discovered that the Town's Engineering Consultants at that time had done studies, including dye tests, at Marblehead's present ocean outfall. The results showed no adverse effects on the ecology, nor any return to shore of the effluent.

This report was buried, and when treatment became mandatory some years later, for some reason the Town's Consultants were changed and the new firm received considerable sums to prove that it was necessary for Marblehead to reverse its largely gravity flow system to a good, open ocean outfall, and build for 7-1/2 million dollars, a pumping station and 4-1/2 mile pipe line over to Salem, a shallow, tidal harbor. The result is really an expensive 'holding tank.'

My indignation at hearing the same firm is now under lucrative contract to the Boston MDC, to quote from the Boston Globe "to marshal scientific data to show there would be no ill effects on the marine environment" - this endeavor is to quality for a waiver to exempt Boston from secondary treatment.

Professor Trump, who also spoke at the September 26 meeting, came to Marblehead and urged our committee to do all we could to prevent the carrying out of this South Essex Sewer Connector Plan. He felt the need for secondary treatment for coastal towns was already being questioned, and believed Marblehead, with its limited population and largely domestic sewage, was an ideal place for an experimental system either his own, or one of the new biological nutrient and water conserving type of systems rapidly becoming available and needing suitable demonstration communities. (Hulls)

> [The sludge management report] picks up the thread running through the other case study reports: the construction grants program, though well intentioned, has tended to lose sight of its water quality objectives through its focus on treatment facilities.
> (Nessen, EOEA)
>
> I agree that we should assume swimming/fishing water quality for Boston Harbor (p.4). And I applaud your statement (10-2) that the objective of water quality management is not a structure but clean swimming/fishing quality water. It seems to me to be perhaps the most important statement which I read in the study. We should emphasize and give priority to actions which will actually take care of the sources of pollution of the harbor:
>
> Primary sludge
> Combined sewer overflows and tidegates
> Sewerline and facilities operationg, maintenance and repair and rehabilitation
> The surcharged MSD system, reducing the volume by 1/1 control, conservation, moratoria, and diversion of upper-watershed sewage to other treatment locations and modes
> Urban runoff
>
> I am wary of using the nearby ocean as an excuse not to treat with secondary treatment, as all inland communities have to, but I do not think that the facility should be designed as a substitute for taking care of the problems listed above.
>
> And, finally, I share the report's fear (10-7) that implementing EMMA (or something similarly massive and expensive) will foreclose other solutions for the remainder of this century. However, I gather that EMMA as an alternative is not in serious contention, since so many segments of it have been questioned by both the Draft Upgrading EIS and by the 208 Areawide Plan, as well as your own report. (Goodhue)

RESPONSE

These comments are illustrative of the varying opinions in the Boston area regarding the need for secondary versus primary treatment for coastal discharges, the relative priorities that should be established for alternative pollution control facilities investments and indeed the rationalizations for those investments. A scientifically defensible and conscientiously developed Water Quality Management Plan adhering to those requirements spelled out clearly in Section 303(d) might have minimized these differences in opinion and levels of understanding among all participants.

COMMENTS

The discussion of Section 10.1 is not entirely accurate. The limiting factors in water quality planning and management are resources and time for data collection and analysis versus legislated deadlines for commitment of funds to meet public demands. Also it is no doubt true that the scientific and engineering understandings of water pollution processes have not been incorporated into the planning process fast enough. However, it is also probably true that discoveries in the field have also moved ahead too slowly as compared to the public demand for clean water.
(Ikalainen, EPA-I)

The discussion in Part 10 ignore a fact of life -- it is time. The technology for combined sewer, urban runoff and nonpoint source pollution control is developing now. It is more advanced today than when EMMA began. Many of the control methodologies recommended in the report are not proven and have not been demonstrated in any real-world situation. The ongoing facilities planning is supposed to seriously consider alternative controls. Water quality management planning today (Phase 2 Basin Plans) will include urban runoff, nonpoint source and combined sewer overflow assessments and controls. Data collection and analysis will support the planning, i.e., Charles River Survey of 1978. (Ikalainen, EPA-I)

RESPONSE

An alternative view might be that limited resources and time have been and are being squandered on planning and construction of facilities instead of developing the water quality management plans which would provide the necessary basis for facilities and areawide plans as well as the necessary design (performance) criteria for facilities or other control alternatives. As for the unproven methodologies examined in this report, it should be recognized that the CSO control methodology assumed in the EMMA Recommended Plan has been neither proven nor demonstrated in the Boston real-world situation to have any significantly beneficial impact on water quality. It should further be recognized that the unproven control methodologies examined in this report (sewer flushing, street cleaning, optimized storage/treatment systems) are precisely the methodologies that are being used to develop EPA's 1978 Needs Survey for Combined Sewer Overflows and Stormwater Discharges.

Among the activities to be included in the Phase 2 Basin Plans as described above, it is noted here that correction of erroneous 303(d) segment classifications and establishment of total maximum daily pollutant loads are conspicuously absent.

COMMENTS

A STAGEWISE APPROACH TO NATIONAL WATER QUALITY GOALS MAY BE BOSTON'S BEST PATH TO CLEAN WATER

BY W. GARY WILLIAMS

CLEARWATER CONSULTANTS

Successful planning for pollution-abating technologies required to achieve National Water Quality Goals depends upon our ability to forecast water quality. If these forecasts are accurate, then it is only necessary to find the most cost-effective plan for achieving waters of fishing and swimming quality. On the other hand, if water quality projections are subject to great imprecision--as I believe is often the case for complex, polluted natural water systems such as the Charles River and Boston Harbor--it may be sounder to adopt a stagewise planning and implementation process for cleaning them. In a stagewise approach, each state of abatement would focus on the current pollution problem of the largest magnitude. At the completion of one stage, the next would be planned incorporating increased knowledge of the waters and water quality improvements accruing from previous clean-up efforts. National Water Quality Goals would be achieved gradually through the cumulative effect of successive improvements in water quality.

As an example of how water quality modeling determines pollution-abatement technologies, let us use a recent analysis of water quality in the Upper and Middle reaches of the Charles River (an analysis of water quality goals and objectives in the Boston metropolitan area, Environmental Research & Technology, Inc., Concord, Massachusetts). The study projects poor water quality resulting from discharges of proposed treatment plants, combined sewer outfalls, and urban runoff; in order to achieve National Water Quality Goals it proposes alternate abatement technologies including land application of treatment plant effluent and intensive street cleaning. These conclusions and recommendations are based on water quality projections derived from an extremely simplified model for phosphate concentrations which may lead to obnoxious algal blooms.

The Charles River flows through a series of impoundments, lakes, and wetlands. In each of these aquatic environments phosphate concentration of the river water is determined by exchanges of phosphate between reservoirs naturally residing in plants, animals, detritus, and sediments. For example, over wetlands phosphate may be removed rapidly from the river water to the sediments because detritus falls quickly through the shallow water column to the muddy bottom, where it is immobilized. It does not seem reasonable to assume, as the study does, that phosphate behaves identically in all sections of the Charles River.

Besides imprecise knowledge of phosphate assimilation within the river system, the magnitude of future sources of phosphates also must be subject to uncertainty. All of these uncertainties should be reflected in the water quality model projections by presenting a range of potential water quality conditions, so that the accuracy of the water quality forecast may be ascertained. For the study cited, it is very probable that water quality projections are imprecise; at different points along the river, actual water quality could be much better or much worse than forecasts indicate.

If at this time there is great uncertainty in projecting water quality for the Charles River, then perhaps this must be acknowledged within the planning process: that attainment of National Water Quality Goals will be achieved at some unspecified time in the future, and not within a relatively short time period. Rather than attempting to abate simultaneously all sources of pollution, the planning process should make treatment of gross pollution problems its first objective, with attainment of National Goals reserved for later stages of pollution abatement. Stagewise planning would allow plans for each successive stage to be tuned according to new information about sources of pollution, new knowledge of natural assimilation processes, and water quality trends attributable to previous stages.

For the Charles River this approach might allow for an initial step of attacking point sources of gross pollution, such as inadequately treated sewage and combined sewer outfalls. After completion of that step, an analysis of remaining pollution sources and water quality trends could be used to plan the second stage facilities and nonstructural solutions.

The success of stagewise planning would be contingent upon acquiring new attitudes toward attainment of National Water Quality Goals and gaining better, more detailed information about the aquatic environment we are trying to improve. Our sense of urgency about National Goals must not be lost, but our anticipations must be tempered according to the depth of current understanding about the aquatic environment. Technical success of stagewise planning requires expanded scientific study of the polluted aquatic environments to quantify accurately pollution sources and natural modes of pollutant assimilation. To describe water quality trends occurring when polluted waters slowly approach fishing and swimming quality, there should be designed and employed qualitative and quantitative tests able to discern gradual but noticeable and desirable improvements.

> The principal benefit of stagewise development of pollution abatement plans is that facilities and nonstructural solutions would be designed from the best available information, which should be of increasing quality as implementation of abatement plans proceeds. Inappropriate or unnecessary techniques dictated by uncertain water quality projections would be avoided. Accurate information about major remaining pollution sources and natural assimilation of pollutants would aid in specifying the capacities and extent of additional abatement solutions. (Williams, Clearwater Consultants)

RESPONSE

This comment deserves a separate response, since it exemplifies an attitude implied by a great many other comments, primarily from those whose primary responsibilities involve the implementation of PL 92-500 and PL 95-217. The argument is loosely paraphrased as follows: "Because our understanding of the real world is not yet precise, why don't we first just try something and see what happens? Then we can try something else and study what happens further. This will take considerable time, and we will have to develop new attitudes toward timely attainment of the National Goals, but, as polluted waters slowly approach fishing and swimming quality, our understanding about the aquatic environment and our ability to accurately quantify our descriptions of it will increase."

The author of this report contends that the approach recommended by Mr. Williams is entirely too similar to the approach that appears to have been followed by the Boston area water quality planners. The objective of the Federal Water Pollution Control Act is not improvement in the precision of our water quality models - it is to restore and maintain the chemical, physical, and biological integrity of the nation's water. To observe that the chemical, physical, and biological processes in natural waters are complex and that our precise understanding of them is in some cases incomplete is to state not only the obvious but the irrelevant. Section 303(d)(1)(C) and (D) recognizes the imprecision of our understanding by the requirement that total maximum daily loads be established at a level....(which includes)... "_a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality_." (emphasis added)

Design models need to be concerned with precision (EPA's SWMM model, for example). The appropriate concern about water quality planning models is not, in this business, with precision - it is with accuracy. The appropriate questions to ask of a water quality planning model follow.

1) Does it accurately reflect the trends observed in nature for the relevant water quality parameters over a sufficiently broad range of conditions?
2) Does it include and distinguish between all known principal sources of pollutants?
3) Does it clearly expose the magnitude of pollutant reductions necessary to achieve water quality objectives?
4) Does it facilitate comparisons among all alternative control strategies under equivalent conditions? and
5) Does it, therefore, suggest to the planner the control strategies most likely to be successful and cost-effective?

The point was made in this report (pp 6-1, 6-2) that the capability for detailed prediction of the temporal and spatial fates of individual chemical and biological species would be of certain scientific and mathematical interest. That this level of precision is necessary for effective water quality planning or management is arguable. The simplistic models employed in this study were intended to demonstrate that rational analyses can be performed and defensible decisions can be made on the basis of available information and that these decisions will be better than those made without any analysis.

COMMENTS

Statements have been made by the author that not one sample was taken during the EMMA study. In fact, measurements and sampling were conducted to estimate infiltration/inflow and in order to characterize certain industrial wastes. At the treatment facilities measurements and sampling are and were conducted as a normal operating rule by MDC. Also water quality sampling and measurements were conducted in the receiving waters during the EMMA study period by various agencies. (Metcalf & Eddy, for MDC)

It is true as ERT has indicated on page 6-1 that little water quality sampling was done during the development of the EMMA plan. However, the EMMA study was based in part on water quality studies of the Charles, Mystic and Neponset Rivers done by the Division of Water Pollution Control in 1973, and surveys of Boston Harbor by the New England Aquarium in 1972 and 1973. Harbor and tributary quality surveys were also conducted in the 60's. (Butler, EPA-I)

(pg 6-1)
The EMMA Study purposely relied on water quality information from federal, state and private studies that were either existing, on-going or proposed during the study period. In addition, the MDC relied on their own long-term plant records for wastewater information. This approach was taken to maximize the use of existing data and avoid duplication. We would also like to point out that the contractor on this study did not conduct any new data collection and in many cases relied on "textbook" values for their water quality predictions. (O'Brien, EPA-I)

(pg 4-19)
With reference to water quality conditions in outer Boston Harbor, the report states: "Bacterial concentrations are consistently in violation of the Class SB water quality criterion throughout most of this section." This statement appears to be in direct conflict with recent sampling conducted by Metcalf and Eddy for MDC's waiver application and should be reviewed in that context. (Ris, BHPAC)

(pg 6-1)
"In the course of a 2-year, $2 million wastewater management study ending with a recommendation for an additional expenditure of nearly a billion dollars of public funds, not one sample of water or wastewater was collected, examine or analyzed." This is a frightening statement. The implications of such irresponsibility have become evident with the results of the sampling conducted for MDC's waiver application, indicating that pollution in the outer harbor is not as bad as previously demanded. (Ris, BHPAC)

(pg 6-1)
Second sentence -- this may be true. However, it points out the lack of data development as part of the decision-making process. (Ikalainen, EPA-I)

Second paragraph, last sentence -- what are the implications of this in considering the recommendations of the report. (Ikalainen, EPA-I)

RESPONSE

The criticism in this report of the lack of sampling and analysis during the EMMA study is in the clear context of combined sewer overflows, stormwater runoff and their resulting impact on water quality. Despite conclusions of the EMMA Study and testimony from all involved agencies and individuals during and since the EMMA Study that combined sewer overflows and stormwater runoff are the primary sources of water pollution in the urban area of Boston, there has been a remarkable lack of demonstrable concern with quantifying or verifying the magnitude of these problems.

The water quality section defined in this report as Boston Outer Harbor is the area in the vicinity of President Roads, where the Deer Island and Nut Island treatment plants presently discharge, and which is consistent with the DWPC classification. The area of concern to the MDC's secondary treatment waiver is some six miles further east in what, more appropriately, is called Massachusetts Bay.

The primary recommendations of this report are that better analyses and planning are imperative if the water quality improvements mandated by PL 92-500 are to be achieved. This report attempted to demonstrate how the analysis and planning process dictated by Section 303 of the Act might be constructively applied, even in absence of adequate data, and how this application would dictate the data requirements of the process.

COMMENT

The title of the report should be changed to show that it is an analysis of alternatives as well as an analysis of goals and objectives. (Cook, EPA-HQ)

RESPONSE

This suggestion has been adopted.

COMMENT

We disagree with the contractor's remarks that there is not accountability in the planning process or that the EMMA plan would have "foreclosed any opportunity..." (O'Brien, EPA-I)

RESPONSE

The precise observation in this report was that "there will continue to be no discernible accountability within either the local, state, or federal agencies or the engineering community for the errors, misjudgements, and technical inadequacies that result in massive public costs with little or no significant water quality benefits." A review of the present status of the individual members of the EMMA Study Technical Subcommittee, and its consultants, continues to indicate no discernible accountability.

This report concluded, among other things, that implementation of the EMMA Plan would have "foreclosed for the remainder of this century any opportunity for swimmable/fishable waters in the Charles River, Neponset and Mystic Rivers, and Boston Inner Harbor." Disagreement with this conclusion by Region I EPA seems inconsistent with Region I's present position as evidenced in comments here that there is not now, if there ever was, any intent to implement the EMMA Plan because of, among other reasons, the failure of major components of the Plan to satisfy water quality criteria.

11.3.2 Combined Sewer Overflows and Stormwater Discharges

COMMENTS

(pg 7-4)
"The discharges to receiving waters of untreated urban stormwater, raw sewage bypasses and combined sewer overflows constitute (1) the most serious of the pollution problems in the urban waterways of the U.S. (Boston included)..." Why then do CSO projects continue to get less points on the state's priority list than wastewater treatment plants? (Ris, BHPAC)

On page 7-4, it is stated that urban stormwater, raw sewage bypasses, and combined sewer overflows constitute the most serious pollution problems in urban areas but receive the least attention of the Construction Grants Program. The 1977 Clean Water Act eliminates federal assistance for control of pollution from separate storm sewers. However, combined sewer projects are grant eligible, if cost-effective and required to protect the beneficial uses of receiving waters. Although provision for funding of secondary treatment of dry weather flows must be made first, we have funded many combined sewer projects and do not consider them to be low priority if needed to enhance water quality. (Cook, EPA-HQ)

Other national program recommendations involved an expansion of research and development efforts, and increased attention generally, to combined sewer overflows and to stormwater, or urban runoff, controls. The Clean Water Act of 1977 requires that EPA report to the Congress by October of this year, regarding combined sewer overflows, and it is clear from report drafts in preparation that the agency on a national scale seriously intends to give greatly increased attention to combined sewer problems. A variety of legislative alternatives will be discussed in the report to the Congress, including a separate multi-billion dollar construction grant authorization for combined sewers, and financial assistance for nonstructural solutions. The draft report discusses analyses made of some of these nonstructural solutions, including the sewer flushing alternative recommended in one of the case studies. The results of these analyses, as reported, allow a comparison of estimated costs and pollution removal efficiencies among the various combined sewer overflow solution alternatives. Although the analyses appear to indicate that overflow storage and treatment can achieve greater pollution reductions at costs equal to or less than sewer flushing alone, it is the expectation of EPA's Region I that a combination of the two alternatives will prove to be the most cost-effective.

This brief discussion of EPA's combined sewer overflows activities should not be ended without mentioning the research and demonstration work that the agency has already conducted. EPA has obligated over $45 million for combined sewer overflow demonstration projects, and the results of these demonstrations will be seen in future CSO projects across the nation.

Not as much has been attempted for stormwater controls although the program is beginning to expand. It is the agency's intention to earmark 20 to 30% of its available Section 208, areawide waste management planning funds for stormwater problems in 20 to 30 urban areas. From this planning effort, a national assessment of stormwater issues will be made, and future control programs will be designed. (Hanmer, EPA-I)

It would be ideal if facilities planning for stormwater discharges was as far advanced as is planning for solutions to combined sewer overflow problems. This is not the case, however; only a small --although significant--beginning has been made. The Metropolitan Area Planning Council, with grant funding under the Federal Water Pollution Control Act's "Areawide Waste Treatment Management" planning authority, has completed a valuable survey of stormwater drainage throughout the metropolitan area. The development of this survey constitutes the first step toward the target of accurately assessing the stormwater problems of the area and devising solutions for them. The next stops should involve facilities planning but, whereas the availability of federal construction grant funds currently gives impetus to facilities planning for the control of human sewage, sewered industrail wastes, and combined sewer overflows, today's pool of grant funds is not large enough to deal with the stormwater problems of the nation Under any circumstances, stormwater treatment will be very expensive. (Hanmer, EPA-I)

(pg 10-5)
The report's recommendation that federal funds be earmarked for CSO and urban stormwater control demonstration projects should be actively pursued. (Ris, BHPAC)

(pg 10-5)
Your recommendation that an expanded R & D program on CSO control is well taken. We feel that the special CSO study that is being conducted under the Clean Water Act of 1977 reflects this same concern. However, we feel that it may be unrealistic to imply that a 5-year R & D program is necessary (followed by local studies) before we attempt to address CSO problems. We feel that with the uncertainties of future federal funding we must proceed with the utilization of existing technologies while concurrently trying to incorporate emerging technologies into the planning process.
(O'Brien, EPA-I)

RESPONSE

These comments contain their own basic response: (1) the 1977 Clean Water Act eliminates federal assistance for control of pollution from separate storm sewers; and (2) combined sewer projects are grant eligible only if they are cost-effective, required to protect the beneficial uses of receiving waters, and provision for funding of secondary treatment of dry weather flows must be made first.

As for EPA's $45 million obligation for combined sewer overflow demonstration projects, this amount represents about two-tenths of 1% of EPA's 1976 or 1978 estimated National Needs Survey for correction of CSOs. In view of the magnitude of the potential costs indicated by every EPA needs survey that has been conducted, $45 million is hardly an impressive investment in technologies that might significantly reduce these future costs.

A minor semantic point - this report did not recommend an expanded R&D program on CSO control. It stated that the control alternatives developed in this study need to be demonstrated by the federal government on a scale large enough to be accepted into the practice of conservative engineering and planning professions, and that the appropriate scale would require between $10 and $50 million for a five-year program. Such a program would, in fact, be an address of the CSO problem. In any event, this demonstration can now be accomplished through the Alternatives and Innovation Technologies provisions of PL 95-217.

COMMENTS

On page 7-5 the high costs for urban stormwater and combined sewer controls are noted. It is stated that cost estimates have been astronomical because of an inability to distinguish between traditional concepts of flood control and pollution control. Considering only the requirements for pollution control, the 1976 Needs Survey estimates needs of $19.3 billion for combined sewers and $57.2 billion for facilities to control stormwater pollution. EPA has provided guidance on determining grant eligible costs of combined sewer overflow projects and on allocating costs (PRM 77-4) of multiple purpose of CSP projects. (Cook, EPA-HQ)

On page 7-5 the ERT report questions the validity of designing combined sewage relieve based on a statistical design storm. I believe the design storm method of sizing combined sewage relieve sewers and treatment facilities is an appropriate and valid method. (Butler, EPA-I)

(pg 7-5)
Last paragraph -- it is good to see this approach applied, but the last sentence is misleading because there was only one application of a model which uses long-term precipitation records. That occurred in the Storage/Treatment Optimization for Storm/Combined Sewers analysis and Appendix F indicates a 14-year meteorological record was used. How might such an analysis be affected by using 20 years or more of record as opposed to the 14 years used in the report? (Ikalainen, EPA-I)

(pg 10-2)
Last paragraph under Section 10.1 - the comments on SWMM are out of date. SWMM will simulate long-term rainfall and any control device which can be suitably programmed. (Ikalainen, EPA-I)

RESPONSE

The discussion on page 7-5 has entirely to do with the common (until recently) practice of designing stormwater and combined sewer pollution control strategies from the design storm approach, which is the basis for flood control planning. The fundamental flaw in the application of the design storm concept to pollution control planning is that it ignores a critical parameter. "No accepted design event condition exists which also specifies a design antecedent dry-weather period." (Pg. 3, Nationwide Evaulation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume I: Executive Summary EPA-600/2-77-064a, September 1977.) The design storm, as a pollution control concept, is simply incorrect. The 1978 Needs Survey recognizes the error of the design storm concept in this application and instead uses continuous hydrologic simulation. "Continuous simulation is a conceptually more realistic representation of the behavior of stormwater/water quality response systems than is the single event simulation used in 1976." (Pg. 1-6, 1978 Needs Survey [Draft]: Cost Methodology for Control of Combined Sewer Overflow and Stormwater Discharge, EPA-430/9-79-003, February 10, 1979.)

Long-term precipitation records were the basis for all stormwater and combined sewer overflow models used in this analysis, including the performance of existing and EMMA recommended detention/chlorination facilities. The analysis would not likely be noticeably affected by increasing the period of record from 14 years to 20 years. The 14 years used included at least one 25-year recurrence frequency storm. More important, it is the distributions of events and event characteristics, rather than the extreme occurrences, that are relevant for pollution control planning, analysis, and design. These distributions, at least for the Boston area meteorology, are not typically subject to wide fluctuations from year to year.

The SWMM model may well simulate long-term rainfall and any control device which can be suitably programmed. It must be frightfully expensive and time consuming, however, to do so and it is certainly unnecessarily complicated. SWMM is and should be used as a design model, not a planning model.

COMMENTS

The findings state that alternate methods exist for combined sewer overflow control that warrant further analysis. This is precisely what is routinely done in the facilities planning process. However, we must point out, as recognized in the case study, that many technologies that appear feasible in theory have yet to be proven or demonstrated on a large-scale basis. (Hanmer, EPA-I)

The Boston Harbor report on water quality prepared by ERT does indicate the major water quality problems that still have to be addressed before full water quality benefits are realized in the Harbor and its tributaries. However, the report falsely implies that relatively inexpensive nonstructural solutions, such as intensive vacuum street sweeping can solve these complex water quality problems. In addition the report contains many errors, in fact, leaves many false impressions, and makes recommendations that are unworkable and/or untested. (Butler, EPA-I)

The statements made in this report, if they are to be reviewed seriously, must be supported with the data base and results upon which they are made. Its author, Mr. J. Douglas Smith, made similar statements regarding the findings of another engineering study in an earlier report of his to the MDC (Pollution Control Alternatives for Dorchester Bay, Process Research, Inc., 1974). In spite of Mr. Smith's contractural obligations, repeated efforts by the MDC to obtain the backup for this study failed precluding any review of the basis of the author's claims. As in this case, the author claimed that water quality would not be improved by the engineers proposal, but that his recommendations, if implemented at a lower cost, would. Until the author has provided the details upon which he has made these claims, it is not productive to analyze the report in detail.

As an example, a claim is made that depending upon the location, 70% to 98% of pollutant removals is required from combined sewer overflows to achieve swimming/fishing water quality and that such would be achieved by a combination of sewer flushing and street sweeping. How this was determined and what pollutants are involved is not clear. However, one only has to briefly assess the present knowledge of the removal capability of pollutants by street sweeping to recognize that such removals cannot be practicably achieved. Further, the street surface (if the entire surface is swept rather than only the gutter) is only a part of the surface upon which pollutants accumulate. Significant areas of roofs, sidewalks, driveways and yards are also contributors. Similarly, sewer flushing, if effective, only attacks the deposited materials in sewers, but does not affect the flowing sewage. The latter has the same, if not higher, concentration of coliforms than the first flush. Mr. Smith needs only to refer to his own measurements at Lowell Street in Cambridge ("Combined Sewer Overflows to the Charles River Basin," Process Research, Inc., 1972) to see this. Therefore, how can Mr. Smith make the claim that "a sewer flushing system and an intensive urban street cleaning program would result in swimming quality water in this area (Inner Harbor)...?"
(Metcalf & Eddy, for MDC)

It is not clear how the contractor's recommended plan of sweeping/flushing/storage addresses the bacteria/virus problem. This issue should be elaborated upon. (O'Brien, EPA-I)

The report considers two alternatives for control of the combined sewer problem. Besides the EMMA recommended detention/chlorination facilities, automated dry weather flushing of combined sewers is considered. Conventional sewer flushing of small pipes may be a viable alternative but there are limitations to the widespread use of automated flushing systems. As noted in the report, field tests have not yet confirmed the effectiveness of such systems for large pipes. While flushing may effectively reduce suspended solids and BOD, its effectiveness is questionable for controlling potentially

> harmful bacteria and viruses. Suspended solids and BOD will deposit in sewers with low gradients and essentially remain until they are resuspended either by flushing or by high flows during wet weather. Coliform bacteria, however, will be deposited and die-off. The remaining bacteria will eventually be resuspended. The die-off rate in the sewers will be slower than those observed in receiving waters because of the absence of ultraviolet light, salinity, and the warmer wastewater temperature. Nevertheless, the report overestimates the removal efficiency of flushing because the bacteria are treated as a conservative (nondiminishing) constituent.
>
> The significance of bacteria die-off within the sewer is uncertain and must be confirmed by field tests. However, it is possible that a substantial proportion of the bacteria observed in combined sewer overflows can be associated with the sanitary wastewater in the sewer rather than the resuspended deposits. Use of the flushing alternative alone would permit continued discharge of untreated sewage from combined sewers during wet weather. While sewer flushing of some of the smaller pipes in a combined system may be worthwhile, such flushing would only be one element of a more comprehensive program required for control of combined sewer overflows. (Cook, EPA-HQ)

RESPONSE

Certainly there are reasonable questions concerning the actual, as opposed to theoretical, pollution control effectiveness that can ultimately be achieved by sewer flushing systems and intensive street cleaning operations. What does, however, seem at this point beyond rational dispute is that they are the most cost-effective first things to do and this is the clear conclusion of the marginal cost analysis employed in EPA's 1978 Needs Survey for combined sewer overflow and stormwater discharge. It must also be pointed out here that the EMMA Recommended Plan assumed a technology that did not appear feasible even in theory.

It is correct that this report treated coliform bacteria, and implicitly viruses and other pathogens, as conservative constituents. There is logic to this treatment, if only limited data. Bacteria and viruses are associated to a considerable extent with the solids fraction of sewage. Any of the solids removal processes conventionally used in wastewater treatment result in disproportionately greater bacteria and virus removals. Conversely, any of the conventional disinfection processes are significantly less effective in the presence of large solids concentrations because bacteria and viruses are shielded by their association with those solids. Furthermore, bacterial concentrations in combined sewer overflows are typically the same or greater than in raw sewage. Since only a small fraction of the volumes of these overflows is represented by the sanitary sewage flowing during the overflow event, the observed bacteria must come from some other source. During the Dorchester Bay study referred to in one of the above comments, coliform concentrations of 2×10^7 organisms/100 ml were measured in a sediment sample collected from the Dorchester Interceptor. As is correctly pointed out in another comment, there is no disinfecting mechanisms present in the sewers. Since there is certainly organic substrate available, a more reasonable assumption might be that deposited bacteria would multiply, though slowly because of lower than optimal temperatures.

In referring to the Lowell Street measurements referred to in the Metcalf & Eddy comment above, no evidence was observed that contradicted the arguments presented here or the assumptions in this report. What was observed, however, was a curious and perhaps significant anomaly concerning overflow data at the Lowell Street station. Metcalf & Eddy, in Volume 7 (Appendix C) of the EMMA Report, claimed to have used the Lowell Street overflow data from the Process Research report: "Combined Sewer Overflows to the Charles River Basin" in order to demonstrate the applicability of the SWMM Model in the Boston Harbor combined sewer area. The "observed" overflow rates presented in the EMMA Report and referenced to the above Process Research report are substantially different from the overflow data actually found in the Process Research report. The peak "observed" overflow rates in the EMMA report, for example, are between two and four times greater than the data in the Process Research report for the two storm events considered by Metcalf & Eddy.

COMMENTS

(pg. 1-15)
The report's recommendations concerning installation of a sewer flushing system and an intensive urban street cleaning program should be actively considered in any future facility plans for correcting combined sewer overflows and runoff problems. Perhaps special funding could be obtained from EPA for demonstrating these technologies in a pilot study area while the recently initiated CSO sampling studies are being conducted. (Ris, BHPAC)

(pg 7-8 and 7-9)
The discussions of Automated Sewer Flushing and Street Cleaning should emphasize they are new technology without sound information on costs, effectiveness, and feasibility. It would be more appropriate to recommend demonstration studies of these controls before offering them as a solution to water pollution problems. Looking back at page 7-6, the discussion of what was thought to be a solution for control of combined sewer overflows (Cottage Farm Station) may have proven otherwise after demonstration.

An unanswered question concerning sewer flushing is: What are the effects of the 3-5% sewage in the overflows that occur after the interceptor capacity is exceeded? Will solids, paper, etc. be visible at the overflow point? Will each overflow need a mixing zone? These are real concerns which cannot be answered by modeling --a large scale long-term (1 year) demonstration is needed.
(Ikalainen, EPA-I)

Because of the large capital costs associated with controlling combined sewer overflows with the usual methods of detection in large tanks with subsequent controlled release, it is certain that the combined sewer overflows facilities planners will investigate operational means to augment the usual means of control. One of these operational means involves sewer flushing, the method recommended in one of the case study reports. EPA has currently engaged a consultant to estimate the specific annual savings that can be gained if sewer flushing is practiced in the Boston Metropolitan area. If the estimate indicates that the savings may be significant, it is likely that the agency will--in the near future--support an MDC sewer flushing demonstration project. The project would be designed for completion in a short enough period of time so that its results could be used by the combined sewer overflow facilities planners. (Hanmer, EPA-I)

RESPONSE

As noted before, there are questions about sewer flushing and street cleaning that need to be answered, and these methods of control do need to be demonstrated on a believable scale. It is, however, unlikely that an adequate demonstration system could be designed, installed, and de-bugged within one year, let alone convincingly demonstrated. A short-term project, designed to provide results for the facilities planning already underway, can probably be assumed to be designed for negative results.

COMMENT

(pp 1-8,9)
The report raises grave questions concerning the proposed construction of additional detention/chlorination facilities based on the design of the Cottage Farm facility in the Charles which reportedly has proven to be totally useless in correcting combined sewer overflow problems. If ERT's analysis is correct, why is the construction of such facilities proceeding at the Warren Avenue Dam, and what steps have been taken to recover funds wasted on the Cottage Farm facility? (Ris, BHPAC)

RESPONSE

As noted elsewhere, not all experiments are successful, nor should conscientious attempts be penalized if they are not completely satisfactory. PL 95-217 further encourages the attempts at new approaches through additional financial incentives and guarantees for Alternatives and Innovative Technologies. The propagation of demonstrably inadequate and/or inappropriate technologies, however, is quite another matter. This goes to the heart of professional incompetence or technical malfeasance.

11.3.3 Wastewater Chlorination and the Secondary Treatment Issue

COMMENTS

The report includes a very interesting discussion of problems resulting from the chlorination of combined sewer overflows and effluents from primary treatment facilities. The report notes the limited effectiveness of such disinfection, the possible production of carcinogenic compounds and the toxicity of the high chlorine residuals. Based on these concerns, the report questions the efficacy of the EMMA recommended detention/chlorination facilities and primary treatment for ocean outfalls. On page 1-16, the report states: "The outfall from the Nut Island primary treatment plant is located at the seaward edge of Quincy Bay and is a major influence on water quality in the Bay." On page 1-19, the report notes further: "If EPA were to discount this (chlorination) practice, secondary treatment would be required at Deer and Nut Islands on water quality considerations alone, regardless of the stipulation of Section 301(b)(1)(B)." Page 4-19 indicates: "Bacterial concentrations are consistently in violation of the class SB water quality criteria throughout most of this section (Boston Outer Harbor). The source of these high bacterial concentrations, however, seems as much the untreated sewage overflows to Boston Inner Harbor as the chlorinated Deer Island effluent. When Deer Island is not chlorinating, however, this situation is reversed and the Deer Island effluent is the primary source of bacteria (and other associated pathogens) in the Outer Harbor and a major contributor to other sections of the Harbor as well." The significance of secondary treatment for ocean outfalls is summarized on page 7-2. "Because of the active biological oxidation and increased solids removal in the secondary (treatment) step, the removal of bacteria and presumably pathogenic organisms increases to 99% beyond that achieved by primary treatment alone. Removal of metals and other contaminants also increases with increasing solids removals."

The above statements indicate that a significant water quality benefit will result from secondary treatment of the ocean discharges. The ERT findings contradict commonly held beliefs. On January 18, 1978, we furnished you with our comments on the Urban Systems Research and Engineering (USR&E) draft Political and Industrial Issues Report. Page 59 of this report states that there is an almost unanimous opinion that secondary treatment at Deer Island is an unreasonable requirement which would probably have no water quality benefit to the harbor or nearby areas. The ERT findings are quite significant because they contradict this assumption. Other contractors working for the Task Force should be informed of these findings. (Cook, EPA-HQ)

It is important to note that the Division has always questioned the need for secondary treatment at Deer Island. In 1974 the Division funded a research project to model Boston Harbor. This model verified that primary treatment was adequate to meet the water quality standards for Boston Harbor. Furthermore, the MDC has filed a Notice of Intent to file for a secondary waiver under Section 301(h) of PL 95-217. The Division is confident that the data presently being collected by the MDC for the inclusion in the waiver application will support the adequacy of primary treatment.
(McMahon, DWPC)

It assumes that disinfection of combined sewers will not be needed with a flushing program, but neglects to give evidence that this will be the case. Further it arouses fear of the use of chlorine as a disinfectant of wastewater based on limited experience with the disinfection of highly treated drinking water. The chlorination of wastewater is accepted practice throughout the nation. While there is research taking place on this subject, at this time there is no other known feasible, cost-effective method of disinfection.
(Weiss, MDC)

(pg 1-18)
The report's concerns regarding the ineffectiveness of chlorination disinfection and the proven carcinogenic effects of chlorinated organic compounds discharged by such systems appear to indicate that we are well on the road to substituting one environmental problem for another. If the report's assumptions in this regard are correct, EPA should conduct an immediate review of the detention/chlorination systems now in operation or under construction in the

metropolitan area and should ensure that full consideration is given to alternative methods in the ongoing CSO studies.
(Ris, BHPAC)

(pg 1-39)
A quote on this page is worth repeating: "If the Boston area assumptions about the effectiveness of chlorinating very poorly treated sewage are in error, or if the chlorination practice is discontinued because of toxicity or other hazards, then the EMMA plan will result in no water quality benefits anywhere in the Boston area." (Ris, BHPAC)

(pg 7-1)
Last paragraph - the discussion of chlorination practices is well taken. Effects of chlorination on biota receive little attention by all involved in water quality planning in the Metropolitan Area. This issue needs probing. (Ikalainen, EPA-I)

(pg 7-2)
Can we have some information on documentation of "increasing observations of tumors in fish and shellfish from waters receiving chlorinated effluents"? (Ikalainen, EPA-I)

(pg 7-2)
It is not clear if the chlorine concentrations discussed here refer to dosage or residual. (O'Brien, EPA-I)

(pg 8-27)
The question of the need for Secondary Treatment in Boston Harbor may never be answered until we advance our understanding of the marine ecosystem and its long-term responses to urban wastes. The chlorination point is well worth consideration if the model used to determine the impacts of secondary treatment is correct.
(Ikalainen, EPA-I)

RESPONSE

For detailed technical responses to all these comments, see: Water Chlorination - Environmental Impact and Health Effects Volume 2, edited by R. G. Jolley, H. Gorchen and D. Hayward Hamilton, Jr., Ann Arbor Science Publishers, Inc. (1978); particularly Ch. 14: "The Toxicity of Chlorine to Freshwater Organisms under Varying Environmental Conditions," by A. S. Brooks and G. L. Seegurt, and Ch. 15: "A Revised Review of the Impact of Chlorination Processes upon Marine Ecosystems: Update 1977," by W. P. Davis and D. P. Middaugh. Both these chapters contain extensive references to the subject matter. Also, for documentation of tumors in fish, see: "Aquatic Pollutants and Biological Effects, with Emphasis on

Neoplasms," edited by H. F. Kraybill, C. J. Dawe, J. C. Harshbarger and R. G. Tardiff, *Annals of New York Academy of Sciences*, Volume 298 (1977).

In general, the chlorination of poorly treated wastewater effluents seems an even more questionable practice today than it was during the period of this study. Observed tumor-like sores around the mouths of white croaker, *Genyonemus lineatus*, collected near the Hyperion sewage outfall in Santa Monica Bay* indicate that the conventional water quality parameters: coliform bacteria, suspended solids, BOD and the like, may be quite inadequate measures of ecological impacts and that the secondary treatment waivers authorized by PL 95-217 will be seriously flawed if based solely on these conventional parameters.

11.3.4 Wastewater Flows and Sewer System Capacities

COMMENTS

(pg 1-10)
Per capita flow figures do not take into account industrial and commercial contributions. (O'Brien, EPA-I)

RESPONSE

The average 240 gpcd flow on which the EMMA Plan was based comprised the following:

residential/commercial	111 gpcd
industrial	32 gpcd
infiltration/inflow	97 gpcd
Total	240 gpcd

COMMENTS

(pg 1-11)
In regards to sewer capacities, the EMMA CSO plan also included additional transmission lines. (O'Brien, EPA-I)

(pg 8-31)
The contractor fails to acknowledge that the EMMA Study also included additional transmission facilities as part of the CSO Plan. (O'Brien, EPA-I)

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*Young, D. H. 1964. "Some Effects of Sewage Effluents on Marine Life," *California Fish and Game* 50(1):33-41.

RESPONSE

The EMMA CSO Plan did indeed include additional transmission lines to carry intercepted overflows to the detention/chlorination facilities. It failed, however, to provide the necessary additional transmission capacities to empty these facilities. "The overflow captured in the detention tanks and the solids and floatables retained would be dewatered into the interceptor system for eventual treatment at Deer Island Treatment Plan. Dewatering would be accomplished either by gravity or by pumping. Either system would be controlled by the available capacity in the receiving interceptor." (emphasis added) (EMMA Vol. 7, pg 5-5). If the EMMA assumed dry weather flows were correct, there would be no available interceptor capacity.

COMMENT

(pg 7-4)
The current flows in the MDC system are about 430 MGD with the proposed design flows at 586 MGD. Please elaborate on the statement that the projected flows are twice the current flows.
(O'Brien, EPA-I)

RESPONSE

It has been documented that about one-third of the flow to Deer Island is seawater inflow through malfunctioning tide gates. If these sources of inflow were eliminated, the actual flows of dry weather sewage would be seen to be less than half the dry weather flows assumed in the EMMA study. Figure 8-1 in this report shows clearly that the measured flows in the Dorchester Inteceptor in 1974 were less than half the EMMA-estimated 1970 flows.

COMMENT

(pg 4-19)
Did the contractor confirm as part of this study that the Port Norfolk Sewer is still blocked? (O'Brien, EPA-I)

RESPONSE

There were no field inspections conducted during this study. The condition noted was the condition during the period(s) of available water quality data.

COMMENTS

This (Kennedy Engineers') report also assumes an artificial gallon per capita wastewater flow rate. This rate is supposedly based on water conservation. While the consultants have information regarding water consumption they did not determine the actual wastewater production rates. Therefore, the nature and degree of water conservation programs is unknown. This may be why the consultants neglected to include any costs associated with water conservation. Furthermore, their flow projections did not include flows generated by sewer flushing as recommended in the Water Quality Report.
(McMahon, DWPC)

Provide incentives for water conservation and reduced flows. Accelerate research to establish minimum stream flow standards and evaluation of groundwater resources; provide incentives for their preservation. Make water conservation mandatory and block expansion of systems. (Brown, BHCAC)

RESPONSE

The "artificial" wastewater flow rate assumed was still 50% higher than measured flows in the Boston sewer system (see pp 8-4, 8-5, of this report). There are, as noted in other responses, no additional flows generated by the sewer flushing systems considered in this study. Sewers are flushed by temporarily stored sewage, not by the insertion of new water. This is explained on page 7-8 of this report.

COMMENTS

The ERT Category I alternatives include sewer cleaning, repairs and rehabilitation to eliminate excessive infiltration and inflow. These measures are assumed to result in significant reductions in the pollution loadings from combined sewers. In developing the costs for Category I alternatives, Kennedy Engineers neglected to include the costs associated with the reduction of infiltration and inflow. Since ERT used the Kennedy estimates, this problem requires correction. The Kennedy Engineers' cost estimates are now being corrected before their report is distributed for review.
(Cook, EPA-HQ)

(pg 1-38)
It is not clear if the costs shown here and on 1-40 include the costs of sewer rehabilitation. (O'Brien, EPA-I)

RESPONSE

The draft version of this report did not include sewer rehabilitation costs. This omission has now been corrected.

COMMENT

On page 10-4 it is stated:

"The cost-effectiveness analysis for infiltration/inflow correction in combined sewer systems for example, is simply wrong. I/I correction costs seem typically to be compared with the apportioned costs of treatment of the additional flows which reach the existing treatment plant(s). The correction costs should be compared with the costs of wet weather overflow control facilities which would be necessary to provide the same level of wet weather pollution abatement, or with the costs of the additional sewerage necessary to make up for the existing wet weather flow capacity occupied by the I/I. The scope of the cost-effectiveness analysis might productively be broadened to consider the costs and/or benefits to all environmental sectors."

PRM 75-34 (PG61) specifies the procedure for analyzing inflow into combined sewers. As stated above, the purpose of the combined sewer analysis is to determine the most cost-effective means of protecting the beneficial uses of the receiving water. The PRM recommends use of a graphical display to aid the analysis of marginal costs and water quality benefits for each alternative. This approach is different from the infiltration/inflow analysis for separate sewers which ERT incorrectly assumes is applicable to combined sewers. (Cook, EPA-I)

RESPONSE

This particular confusion might be clarified by changing the text to read "infiltration," rather than "infiltration/inflow." This has been done. It should be understood, however, that the dry weather inflows through malfunctioning tide gates in the Boston area are to be included within this definition of infiltration. The point remains that the analysis for correction of extraneous dry weather flows into combined sewer systems is wrong and for the reasons stated. PRM 75-34 does not address this point.

11.3.5 Operation and Maintenance Costs

COMMENTS

On page 14 of the Executive Summary, it is stated that the absence of Federal participation in funding O&M costs acts to bias the planning process toward large and highly capital intensive construction projects at the expense of adequate O&M of existing or small systems. We do not believe that a Federal grants program of subsidies for O&M will necessarily result in the implementation of more cost-effective pollution control projects or improved O&M for projects once constructed. Our cost-effectiveness analysis procedures are based upon total costs irrespective of Federal and State cost sharing formulas. (Cook, EPA-HQ).

The recommendation appears to be primarily based upon an observation of planning for control of combined sewer overflow in Boston. Under Section 516(c) of the 1977 Clean Water Act, a report has been prepared for Congress on combined sewer overflows which includes recommendations for grants programs. This report considers five funding alternatives including modification of the current law to provide funding for nonstructural control techniques. The report finds sewer flushing to be the most cost-effective nonstructural alternative but concludes that potential cost savings associated with nonstructural management practices may be more theoretical than actual. The report recommends continuing the present practice of funding capital construction costs. (Cook, EPA-HQ)

(pg. 10-6)
Although the contractor's proposed system of basing the Federal Grant on a projects present worth may be calculated "relatively easily," we feel that the contractor did not address the more complex issue of assuring that proper O&M is carried out over the life of the project especially for alternatives such as street sweeping and flushing as the contractor recommends.
(O'Brien, EPA-I)

The Division is in agreement with the reports recommendation that the EPA institute Operation and Maintenance grants. We feel that communities need financial assistance to help pay for the high operational maintenance costs and also this would help assure proper operation for the plants. (McMahon, DWPC)

RESPONSE

It is granted that the assistance value of federal participation in O&M costs may be more psychological than economic. Nevertheless, the phychological value seems real. Basing annual payments of federal

O&M grants on annual demonstrations of proper O&M would seem to provide a reasonably useful and incentive producing tool. The 1978 Report to Congress on Combined Sewer Overflows may have been premature in its recommendation, because not enough performance or cost information regarding non-structural alternatives was considered to exist at this time to warrant such major program modifications. The intent of the Alternative and Innovative Technologies provisions of PL 95-217, however, seems to be to encourage the rapid development of this information.

11.3.6 Water Quality Benefits Analysis

COMMENTS

On page XIII, it is implied that no water quality benefits would accrue by implementing the EMMA plan. I disagree - Reducing raw overflows of combined sewage, as described above, result in significant water quality benefits. Admittedly, the urban runoff problem must be evaluated and solved before full realization of water quality goals can be achieved. The report fails to acknowledge the incremental benefits that would occur from combined sewage abatement, such as an improved fishery in the lower Harbor and tributaries without necessarily achieving a swimming quality. (Butler, EPA-I)

We feel that the assumption that a project has no benefit unless it results in an upgrading of water use class is too restrictive. Class violations are frequently caused by a variety of problems and hence require a variety of solutions. As individual components of an overall plan are completed, incremental benefits accrue. Simply because a single project does not, in and of itself, solve, say, a coliform problem does not mean that no benefits were achieved. Incremental increases in D.O. levels or reduction in the frequency of beach or shellfish closings represent benefits that are not acknowledged by the contractor's system. We can not outline a specific alternative system other than to request that incremental benefits be considered or at least acknowledged. (O'Brien, EPA-I)

In reading Chapter 9, it appears the consultant only considers water quality benefits when a quality suitable for swimming is achieved. The report does not include benefits that may occur from incremental water quality improvements such as restoring or improving an existing fishery to a waterbody. (Butler, EPA-I)

The assertion that water quality benefits accrue only when there is a major change in water use does not appear to be consistent with the national policy to move in progressive steps towards achievement of water quality objectives. In this same context, the report does not recognize the benefits of achieving water quality objectives most of the time and only provide recognition of benefits if the water quality levels are achieved continuously. (Butler, EPA-I)

(pg. I-4)
Was the contractor able to correlate any of the projected water use potential figures with actual water use figures in existing clean segments? Or for that matter in any segment regardless of existing water quality?

General - The contractor has directly equated water use potential with benefits. We feel that this is somewhat misleading. It implies to the public that an area with higher benefits has higher water quality, when actually it just means that there is a larger adjacent population center. The system does not distinguish between different uses, i.e., bathing, fishing, boating. The system does not account for the non-human beneficiaries, i.e., fish and aquatic life, of clean water. If a body of water is clean, but not near a population center, there are very little benefits. We feel that since the suggested system is rather specific, likewise its title should be specific and not use the broad term "benefit". (O'Brien, EPA-I)

Appendix I - GOOD, but clean water perceptions vs. realities may be a problem. (Ikalainen, EPA-I)

RESPONSE

There is confusion in some of these comments between costs and benefits. Reducing raw overflows of combined sewage is a cost, not a benefit. A benefit only occurs when a greater water use, or potential use, is realized. If raw overflows are reduced, but not sufficiently to permit a greater water use, then a cost has undoubtedly been incurred, but no economic theory would propose that a benefit has been realized. This report considered costs and benefits of overall plans only, and not of the individual projects comprising the plans.

The arguments that increased periods of water quality criteria satisfaction should be considered as benefits have a certain logic but present unnecessarily difficult enforcement problems. This report considered and resolved this issue within the recommended water quality criteria where, for example, average monthly coliform concentrations were specified. The report thus defines certain water quality objectives in "most of the time" terms, that is, those most relevant to beach and shellfish bed closings. Others, where appropriate, are necessarily defined as continuous. Salmon fingerlings, for example, need D.O. levels of 5 mg/l continuously, not "most of the time."

This writer is unfamiliar with "the national policy to move in progressive steps towards achievement of water quality objectives." The July 1, 1983 date for attaining "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water" [PL 92-500, Sec. 101(a)(2)] would not seem to allow a great number of steps.

Finally, it is after all the public that bears the costs of the various pollution control plans and programs and realizes such benefits that may result. This study, therefore, considered the public's reported "willingness to pay" for such benefits as a reasonable measure of the public valuation of those benefits. The analyses of this sort that were available (see page 9-2) suggested strongly that "public priorities are influenced primarily by public proximities." It is made quite clear in this report (pg. 9-2; Appendix I) that the potential benefits of clean water in one location were evaluated with the assumption of equally acceptable water quality at all other locations. The "benefits" model, thus, does indicate that the greatest potential clean water benefits are nearest the greatest population concentrations, and that there are relatively little benefits associated with clean water far away from a population center. That is precisely the conclusion of the available willingness to pay surveys, and the correlations leading to this conclusion are included in the references indicated at the top of page 9-2 of this report.

11.4 Technical Questions and Comments

11.4.1 Water Quality Standards

COMMENTS

(pg. 3-3)
Quotation--Technology limiting exceptions may still apply.
(Ikalainen, EPA-I)

RESPONSE

It has been a contention of this report that technology-limiting exceptions do not occur. It is techology-limited water quality management planning and planners that occur.

COMMENT

(pg. 3-16)
Part 3.3.1--Water uses such as bathing may be limited by "conditions resulting from natural origins." It is incorrect reasoning to set criteria for uses which do not account for such conditions. The Charles River is an example in which it is desirable to set standards so the water is not a public health problem when used, but it may not be so desirable to attempt to have water appealing for swimming in the wetlands and swampy reaches of the river where natural conditions prevent swimming. (Ikalainen, EPA-I)

RESPONSE

"It is the national goal that...water quality which provides for... recreation in and on the water be achieved by July 1, 1983;..." [PL 95-500, Sec. 101(a)(2)]. It should be noted that all the wetlands and swampy reaches of the Charles River were reclassified in 1978 by DWPC as Class B (swimming) waters. The criteria recommended in this report (see, particularly, color, and turbidity) furthermore take into adequate account considerations such as shallowness of depth, etc., without resorting to such definitional vaguenesses as "conditions resulting from natural origins."

COMMENT

(pg. 3-18)
Recommended criteria for fecal coliform bacteria--time spacing between the five sample sets should be specified. (Ikalainen, EPA-I)

RESPONSE

The implication seems clear that the five sample sets would be spaced about evenly. Any further precision would likely create more enforcement and legal problems than it would solve.

COMMENT

(pp. 3-20, 21 Table 3-7)
The recommended criteria for nutrients - 25 ug/l of chlorophyll-a relates only to the standing crop of plankton. How does this relate to rooted aquatic plants? Will phosphorous and nitrogen available after institution of the recommended controls be sufficient to support plant growth? (Ikalainen, EPA-I)

RESPONSE

The recommended criteria do not relate to rooted aquatic plants but to algal biomass and its impact on water clarity. Adequate nutrients would undoubtably remain to allow suitable plant growth but probably not offensive plant growth.

COMMENT

Appendix A is not applicable any longer. (Ikalainen, EPA-I)

RESPONSE

Appendix A has been retitled Appendix A-1 and includes the Massachusetts Water Quality Standards in effect during this study. Appendix A-2 includes the standards as revised in April 1978.

11.4.2 Models and Modeling Assumptions

COMMENT

(pg. 4-1)
Controlling Water Quality Parameters. Selecting a controlling parameter for each water body infers that other parameters need not be evaluated. It would be reassuring if all pollutants causing problems were evaluated and if recommended controls were demonstrated to consistently and reliably handle those pollutants assumed away in the analysis. (Ikalainen, EPA-I)

RESPONSE

The discussion on pp. 4-1 and 4-2 makes clear that other parameters are, in fact, evaluated and that the controlling parameter (or parameters) is that parameter which, if reduced to an acceptable value by any of the control strategies examined in this study, would also result in acceptable values for all other parameters. No pollutants were "assumed away" in this analysis.

COMMENT

(pg. 2-3)
Last sentence under Part 2.4--Does Biochemical Oxygen Demand, as used here, include nitrogenous demand as well as carbonaceous? It should and should be explained as such. (Ikalainen, EPA-I)

RESPONSE

Biochemical oxygen demand, as used throughout this report, is 5-day BOD. The text on page 2-3 has been corrected to clarify this point. BOD, neither 5-day nor ultimate, does not control water quality in Boston Harbor or tributaries.

COMMENTS

Was the Charles River Model adapted to simulate BOD and coliforms in the river and is this how the loadings in Tables 5-1, 5-3, 5-4, and 5-6 were developed? (Ikalainen, EPA-I)

(pg. 5-6)
Pollutant loading factors for urban stormwater runoff are oversimplified. Within the categories of Residential, Commercial, Industrial, and Other, there are numerous differences which have different loading rates. For example, density and age of residential development generate different loadings (refer to Brockton, Mass. 208 Analysis). (Ikalainen, EPA-I)

In Section 5.2, pollutant loadings are expressed as pounds/acre-year and pounds/capita-year. Loadings distributions in Tables 5-1 to 5-6 are expressed as pounds/day. In Appendix D, M_p and M_{np} are phosphorus loadings in pounds/day.

What was the procedure for daily loadings distributions development? Elaborate on this explaining the real-world stochastic nature of loadings from runoff and nonpoint sources vs. the procedure used. (Ikalainen, EPA-I)

RESPONSE

The loadings in Tables 5-1 through 5-6 were developed from the procedures described in Section 5 as applied to the land use distributions in Appendix C. The Charles River Model was not used in the development of these loadings. Pollutant loading factors for urban stormwater runoff are, if anything, more complicated than necessary. The estimation method used was based on the method developed by Heaney, et al. because that method was being widely used elsewhere (see, for example, the 1978 Needs Survey and the 1978 EPA Report to Congress on Combined Sewer Overflows). Subsequent comparisons of results from an alternative estimation process where loadings were simply proportional to populations showed no significant differences between the two methods. Of course, some actual runoff quality/quantity data might show either method to be inadequate, but no such data was available from the Boston study area.

Daily loadings were simply annual loadings divided by 365 to reduce the size of the numbers in Tables 5-1 through 5-6.

The real-world stochastic nature of loadings from runoff and nonpoint sources was accounted for in the water quality criteria recommended in this report, e.g., monthly coliform averages.

COMMENT

(pg. 5-7)
Isn't combined sewer overflow water comprised of urban stormwater + resuspended dry weather sewage pollutants + dry weather sewage pollutants in the system at the time of the storm event? Have these been accounted for? (Ikalainen, EPA-I)

RESPONSE

The dry weather sewage pollutants flowing in the system at the time of the storm event are not accounted for in Tables 5-1 through 5-6. Pipe originating loadings are, thus, underestimated by about 5% in these tables (this point is now clarified in the text).

COMMENT

On page 5-6, it is stated: "Loading factors for nitrogen (N) and BOD were directly from Heany et al. Those for phosphorus (P) were five times those used by Heany et al., to simulate more closely phosphorus concentrations reported for urban stormwater runoff (EMMA, Vol. 8; APWA 1977)." This is a major assumption which greatly affects conclusions regarding the need for urban stormwater runoff control since phosphorus is the controlling substance. The justification for this assumption should be explained in more detail in the final report. Had this assumption not been made, there would be an 80 percent reduction in stormwater loadings from those used in the water quality simulations. This is also significant because the report cites the need for street sweeping to control stormwater pollution. The street sweeping technology recommended exceeds current technological capabilities. Moreover, every city street would have to be swept once every day. (Cook, EPA-HQ)

RESPONSE

It is true that this is a major assumption. It was judged necessary for the reason stated: because the Heany et al. loading factors did not result in runoff concentrations sufficiently comparable to observations. Until the appropriate data are collected, this particular uncertainty will probably remain unresolved. A couple of remarks, however, might place the uncertainty in perspective. First, if the assumption had not been made, the 95% street cleaning requirement would have been reduced to 75% and Figure 8-7 indicates that the street cleaning cost differential between the alternative assumptions would be small compared to that for any of the other stormwater control alternatives. Second, since the observed phosphorus concentrations must originate somewhere, lesser assumed stormwater loadings must necessitate larger loadings from other point or nonpoint sources and consequently more severe control strategies than those assumed necessary in this report. Again, some appropriate data would be useful.

COMMENTS

> Another important assumption which affects the phosphorus simulation is explained on page 6-7. A problem results from the simulation of nonsteady-state rainfall events by using steady-state techniques. The phosphorus model model simulates water quality for a seven-day 10-year low-flow condition. Stormwater runoff and combined sewer phosphorus loads are considered but nonpoint source loads are not. It seems more reasonable to consider all three loads in the same manner. The elimination of nonpoint source loads may, in part, have been responsible for the need to increase urban stormwater phosphorus loads by a factor of five. (Cook, EPA-HQ)
>
> (pg. 8-38 last paragraph)
> I doubt if assumption of zero nonpoint source contributions to Charles River at low flow and the resulting effect is correct. The reason is that low flow conditions will be affected by phosphorus and nitrogen in the river system which has not passed out of the system. At low flow the time of passage through the entire river from Milford to Watertown is many weeks. Low flows will not last many days and thus the river will almost always be carrying some nonpoint source loadings. (Ikalainen, EPA-I)

RESPONSE

It seemed acceptable to consider that runoff from previous areas (nonpoint sources) will be disproportionately small (whether or not exactly zero) for some time before, as well as during, the 10-year, 7-day low flow conditions. A natural condition for the 10-year, 7-day low flow will be a serious depletion of soil moisture and lowered ground water table, both of which would preferentially absorb runoff. Runoff from impervious areas (urban stormwater), conversely, will flow to the river no matter what the previous meteorological history. The description in the above comment of the fate of nonpoint source loadings is incorrect for nonpoint sources but correct for urban stormwater runoff.

COMMENTS

It appears that the model does not account for phosphorus sources such as precipitation or uptake from sediment. It has been shown that total phosphorus is transported by a deposition-resuspension process in rivers. Thus the phosphorus model may not account for all phosphorus in the river system and control strategies based upon it may not prove to be as effective as assumed.
(Ikalainen, EPA-I)

The suspicion of low phosphorus loadings as reported by MDWPC for upstream treatment plants may arise in part from a decay rate which is too high and phosphorus from other sources such as sediments and unaccounted for non-point sources. (Ikalainen, EPA-I)

RESPONSE

The model is purposely not based on any particular mechanism or combination of mechanisms. It is strictly an empirical model describing the observed behavior of phosphorus concentrations in the Charles River. As such, it implicitly accounts for such mechanisms as exist although it does not do so explicitly.

The suspicion of low reported phosphorus loadings for upstream treatment plants arises entirely from the large discrepancies between measured phosphorus concentrations immediately downstream from those plants and the much lower concentrations that would result from the reported loadings. As noted in response to the next series of comments about the phosphorus model, the decay rate assumed in this study may well be too low.

COMMENTS

(pg. 2-3)
Part 2.5 -- Empirical models are representative of the data that was used to develop them and as with all other mathematical models should be calibrated and verified with independent sets of data, excluding the data used to develop them. To what extent was this done in the report and what are the specific data limitations for each model. (Ikalainen, EPA-I)

(pg 6-2)
What data, specifically was used to develop the phosphorus decay rate. Was phosphorus flux computed for Q CRV = 147 cfs, 116 cfs and 88 cfs as calibration of the phosphorus decay model. If so, why isn't it shown in Figure 6-1? (Ikalainen, EPA-I)

(pg 6-6, Table 6-1)
The title of this table indicates that the model was only run for one day of the four days for which there are phosphorus data (6/26, 28 and 9/4, 6, 1973). The September data for 1973 indicate that phosphorus fluxes in lower river reaches (above Watertown Dam) increase at downstream locations (r.m. 18.3 vs. r.m. 12.7) and, therefore, a decay coefficient of 0.1 day^{-1} is not appropriate. This means that phosphorus modeling is extremely complex and simple empirical models may not be representative or usable for assessing control strategies. (Ikalainen, EPA-I)

(pg. 6-4)
Can "adequate representation" be quantified more in the first full sentence on this page. (Ikalainen, EPA-I)

(pg. D-1)
How was the rate constant of 0.1 day^{-1} developed? (Ikalainen, EPA-I)

(pg. D-2)
Was computation and comparison done for Sept. 1973 data as well? If not - why not? Wouldn't this tell more about model's ability to accurately represent phosphorus fluxes. (Ikalainen, EPA-I)

RESPONSE

These comments are well taken. As described in pp 6-4 through 6-7 of this report, there are serious discrepancies between reported point source phosphorus loadings and observed concentrations in the upper Charles River. Additionally described were the difficulties of streamflow estimation in the upper river and with relationships between streamflow and nonpoint source loadings. The judgements made during this study were that: (1) actual upstream flow rates during the 1973 sampling periods were of sufficient uncertainty that modeling discrepancies were ignored in this area; and (2) nonpoint source loading estimates were annual averages and, as such, were applicable only to average stream flow values. As such, the phosphorus model was calibrated only with the June 1973 data, where streamflows were near to the annual summer flow average. In this calibration, a phosphorus decay coefficient of 0.1 day^{-1} seemed to represent the available data. It also seemed reasonable for the September low stream flow data, but only if the nonpoint source loadings were ignored. The additional comparisons are not shown on Figure 6-1 because it is fairly cluttered already.

An alternative interpretation could as well be made by assuming more typical phosphorus concentrations in the point source discharges. If, for example, the actual point sources were two or three times those reported and all loadings were considered independent of streamflow, then phosphorus fluxes could be fairly closely approximated for all four sampling dates using a decay coefficient of about 0.25 day^{-1}. In either case, it should be noted, the model will predict the observed increases in phosphorus flux between Mother Brook and the Watertown Dam. This is because of the relatively large increase in urban stormwater runoff from the Newton area along this section.

The interpretation made in this study was considered as the more conservative. It demanded the greater loadings reductions to satisfy water quality criteria and this included the "margin of safety" required by Sec. 303(d)(1)(c).

COMMENT

(pg. 8-20)
Last sentence -- This sentence leads to the conclusion that separate urban stormwater runoff by itself will not cause coliform concentrations to exceed standards in all areas of the harbor. This conclusion is based on modeling which considers large areas of the harbor and instantaneous, continuous mixing of runoff and pollutants. However, what happens in the nearshore zone from the land-water point to 100 feet off-shore? Won't suspended solids be visible and coliform concentrations be high in this zone of high water visibility and contact? Should planning consider extension of storm drains to deeper water some distance offshore?
(Ikalainen, EPA-I)

RESPONSE

The zone of passage criterion (see page 3-37) recommended in this report was designed specifically to allow accommodation of the kinds of temporal and spatial quality variations described above.

COMMENT

(pg 6-4)
Last sentence in first paragraph -- The calibration of the STREAM model by the MDWPC and in the EIS modeling was based upon flow measurements of the upstream flows in the Charles and its tributaries not just the flows at the Charles River Village USGS gauge. Thus the model is calibrated to represent pollutant distributions in the river at measured flow conditions. (Ikalainen, EPA-I).

RESPONSE

This might be true, but not likely. The numbers of 1973 flow measurements in the Charles River upstream of the Charles River Village Gage totalled six from only two locations (DWPC, 1974). The specific description of low flow calculations used for the Charles River by the DWPC STREAM Model is on page 70 of the Charles River Basin 1976 Water Quality Management Plan (DWPC, 1976a): "The calculated low flow" for each reach bears a ratio to this flow [11.6 cfs at Charles River Village] equal to the corresponding ratio of drainage areas." What may have been the intent of the above comment was that the STEAM model calibration was based upon time of travel measurements in upstream reaches of the Charles.

COMMENT

(pg. D-2)
Next to the last sentence -- sampling by EPA and DWPC was done during three one-to-two-week periods in 1967 and 1973 and is not two years of sampling. Was PRI sampling done over several days, weeks, months? (Ikalainen, EPA-I)

RESPONSE

PRI sampling was approximately monthly during four-month periods in each of the three years noted. This data, as is described, constitutes all the available data at this location from the seven years of record.

COMMENT

(pg D-7)
Parameter values of a_N and a_P are from Potomac River estuary. What is available for information to indicate these are representative of the Charles River? (Ikalainen, EPA-I)

RESPONSE

The Potomac River estuary parameters of stream flow, tributary area, tributary populations, combined and separate sewered areas, etc., are closely proportional to the Charles River though about an order of magnitude greater.

COMMENT

(pg. D-17)
It is not clear why the contractor assumed that the (chlorinated?) effluent coliform concentration from Deer Island is the same as the unchlorinated effluent. (O'Brien, EPA-I)

RESPONSE

The Boston Harbor coliform data, in the near vicinity of the Deer Island effluent plume, were not significantly different during the 1968 summer, when Deer Island was reportedly chlorinating, from the 1969 winter when Deer Island was reportedly not chlorinating.

COMMENT

(pg F-1)
Specific input conditions for the model were So. Boston portion of ERT Dorchester Bay Model? (Ikalainen, EPA-I)

(pg. F-9)
Figure F-1 is confusing. (Ikalainen, EPA-I)

RESPONSE

The specific input conditions were those listed on page F-1. The model was the South Boston portion of the ERT Dorchester Bay Model.

The equation numbers on Figure F-1 have been corrected, which should clarify it greatly.

11.4.3 Sewer Flushing and Street Cleaning

COMMENTS

The report criticizes the chlorination detention facilities and recommends instead, flushing up to 3 times per day along with street vacuuming. The flushing will require substantial amounts of water and capital investment. The Corps of Engineers Northeast Water Supply Study stated that the metropolitan area water supply resources were inadequate. The report does not address this. The facilities planning report by Kennedy Engineers recommends decreasing water use. This is in direct conflict with the Water Quality Report recommendations. The water quality report also found that separated storm water discharges have a significant impact on water quality. The Kennedy Engineers report recommends separation, however, the report did not include any storm water treatment costs. Here again the reports contain conflicting recommendations. (McMahon, DWPC)

On page 8-2 it is stated that all ID options include 100 mgd of additional wet weather capacity at Deer Island. The report assumes the extra capacity is necessary to treat wastewater from combined sewer flushing. If so, the inclusion of this extra capacity for other alternatives appears unwarranted. (Cook, EPA-HQ)

RESPONSE

There is no additional water used in the sewer flushing systems described in this report. The flushing water is the sewage that is already in the pipes. The 100 mgd of extra capacity at Deer Island has nothing to do with sewer flushing. It is intended only for treatment of the wet weather inflow to the combined sewer system up to the available interceptor capacity in the existing system to eliminate wet weather by passing at the treatment plant.

COMMENTS

(part 7)
Discussions under this section should include information on how management and operational skill intensive each control is. In considering a pollution control alternative such as sewer flushing and intensive street cleaning, the details of implementing the control should be part of the alternative evaluation phase. (Ikalainen, EPA-I)

As for the report on water quality objectives it contains a specific recommendation. It advocates that street cleaning and the flushing of local sewerage systems is the answer to the problem of combined sewer overflows. It contends that flushing devices can be installed and operated at a fraction of the cost of structural improvements.

The report does not discuss whether flushing and street cleaning alone will be adequate to achieve solids removals or whether additional facilities will be needed, although the report indicates that intensive street cleaning programs is an untried method of pollution control. Finally, there is no recognition of the management issues or any backup for their cost estimates on implementing a flushing program. (Weiss, MDC)

RESPONSE

There are no immediately obvious differences between the management skills required of the alternatives considered in this report or any other workable alternatives. The effective functioning of a secondary treatment plant at Deer Island, for example, would necessitate a far more dedicated and intensive sewer monitoring and tide gate management system than presently exists. The activated sludge organisms would not be able to tolerate the twice daily salinity fluctuations that presently result from malfunctioning tide gates. Whether or not the necessary management skills exist within the present Boston area pollution control infrastructure, the necessary skills are not functionally dependent on control alternatives.

Required operational skills are a somewhat different matter. Automated operation of sewer systems (flushing, in-line storage, etc.) obviously will require different kinds of operating skills than, say, land treatment systems or street cleaning operations. No evidence was found during this study, or since, that any of the kinds of required skills are in shorter, or as short, supply than qualified operators of conventional sewage treatment plants.

COMMENT

(pg G-1)
The opening sentence here implies that there was a pipe-by-pipe analysis performed as part of this study. Was this the case?
(O'Brien, EPA-1)

RESPONSE

Yes, it was. The data bank enabling this analysis, however, was developed in the Dorchester Bay Study conducted by Process Research for the MDC and included in Appendix IV of that report.

COMMENT

(pg 7-7)
Please provide an estimate of the number of automated in-line storage systems in the U.S. (O'Brien, EPA-I)

RESPONSE

The oldest such systems are in Seattle, Washington, Detroit, Michigan, and Minneapolis - St. Paul, Minnesota, the Seattle system (CATAD) having been in operation since about 1971. The 1978 Needs Survey lists seven references for such systems.

COMMENT

(Appendix G)
Where is flushing effectiveness analysis and the problem treatment. Apparently pollutant reductions are assumed and applied as such in Chapter 8. (Ikalainen, EPA-I)

RESPONSE

Necessary pollutant reductions were estimated in Chapter 8 by water quality models. The required numbers of flushing (and in-line storage) stations to achieve these reductions were estimated from the equations in Appendix G.

COMMENTS

The contractor's recommended plan on CSO control should be described in more detail to include: Number of flushing stations and sweepers needed, area to be covered, frequency and duration of flushing and sweeping, need for any off-line storage and/or chlorination, mention of 3200 miles of sewer rehabilitation. (O'Brien, EPA-I)

(pg 8-22)
This section should include information on the number of flushing stations and street sweepers needed, frequency of flushing and duration of daily sweeping for the Boston Case. (O'Brien, EPA-I)

We suggest that ERT consider another combined sewer control alternative featuring limited upstream flushing of smaller pipes, holding basins at strategic points in the system, rehabilitation of sewers and regulatory works, and finally treatment of the stored flows during off-peak periods at the plants. (Cook, EPA-HQ)

On page xiii necessary removals of pollutants from combined sewage and urban runoff are indicated. I assume these levels apply equally to all pollutants such as BOD, suspended solids, nutrients and coliforms although it is unclear. It is unlikely that the recommended intensive vacuum street sweeping and the combined sewer flushing can accomplish these removals. I agree with ERT that

> non-structural controls to urban runoff and combined sewage must be further evaluated and at a much greater effort. However, rather than relying solely on non-structural controls, they should be evaluated along with structural controls that may be needed. Hopefully, non-structural controls will be fully considered in the current combined sewage abatement facilities plans. (Butler, EPA-I)
>
> The report recommends non-structural solutions such as sewer flushing and street sweeping for correction of combined sewer overflows. Recent research of sewer flushing has shown that it does not reduce the need for off line storage. This will add costs which will probably make sewer flushing economically undesirable. However, flushing will be one of many alternatives addressed in the facilities plan studies of combined sewer overflows recently initiated by the MDC. (McMahon, DWPC)

RESPONSE

There is no recommended plan in this report for CSO control or any other pollution source. There was a recommended approach to planning. None of the alternative strategies examined in this analysis was intended to represent the optimal or worst cost-effective combination of alternatives. Each was used only as an example to demonstrate an approach to water quality management planning that was based on the requirements of water quality. The preface of this report futher makes clear that "This is not intended to be a "counter plan" or an adversary document. Rather it is an examination of results, how they were arrived at, and how alternative analyses could have provided different and more productive results."

The most intensive sequence of sewer flushing and street cleaning alternatives examined in this analysis, Alternatives ID2&4 a-d, involved 3,254 flushing and in-line storage stations in 9,725 acres and 436 vacuum street cleaners covering 144,406 acres. For costing purposes, one flushing/storage station was assumed for every pipe component (192 foot mean length) flushed. In fact, the proximity of many of these components to each other would result in far fewer stations, probably about one-third, than were assumed. Flushing frequencies would be several times per day. The street cleaning frequency assumed was once per day.

Flushing systems should not be designed on the basis of pipe size or location. A cost-effective design would be based upon where the heaviest deposits are. In Dorchester, for example, 18% of the total deposition occurs in only four pipes, all of which are in the downstream trunk sewer and single station. Figure 8-7 provides a basis for imagining a more nearly optimal combination of alternatives than those examined in this study. This figure indicates that, depending on assumed deposition rates, wash-off formulations, sewer system configurations, etc., removing the first 40% to 70% of coliforms in pipe deposits by flushing (and in-line storage) and the first 50% to 80% of coliforms on street surfaces by street (vacuum) cleaning and then adding offline storage with ultimate treatment at Deer Island would result in a more cost-effective combination than any of the three alternatives alone. An effective facilities planning process would presumably follow this approach, as does the 1978 Needs Survey.

COMMENTS

(pg 8-24, 1st Paragraph top of page)
This paragraph indicates the unknowns concerning street cleaning. Cleaning frequencies are highly variable as estimated and are not demonstrable by actual practice. Note that vacuum equipment at a cleaning frequency of once per day is assumed in the analysis of costs of controls. (Ikalainen, EPA-I)

Equipment costs are based upon vacuum equipment but none exist (pp. 7-9) which can work between and under parked cars. Therefore, how meaningful are equipment costs? Also, how were costs for equipment developed as related to miles of gutters to be cleaned? (Ikalainen, EPA-I)

(Remainder of Section 8.3)
This reads as though all of Metropolitan area will have streets cleaned daily. What are some other factors not mentioned which could affect such a control. Some potentials are traffic problems, parking needs, disposal of materials picked up--volume, disposal sites, etc. (Ikalainen, EPA-I)

RESPONSE

Streets in some sections of the Beacon Hill area of the City of Boston are presently swept at a frequency of once per day. Equipment costs were based on existing equipment and related to miles of gutters (see pp E-6, E-7). It was stated on page 7-9 that equipment could be developed to clean around and under parked cars as a response to the major difficulty posed for this control method (parked automobiles).

COMMENTS

I fail to see how intensive urban street sweeping produces air quality benefits as indicated on page 10-4. (Butler, EPA-I)

(pg E-6)
There was no efficiency curve provided for the vacuum sweepers. (O'Brien, EPA-I)

(pg E-24)
We question the feasibility of suggesting a daily street sweeping program for a 25,000 acre area. (O'Brien, EPA-I)

RESPONSE

A substantial fraction of urban air particulates and fugitive dust (about 20% cycles between street (and other impervious) surfaces and the atmosphere. If these materials were picked up from the street surfaces, they would no longer be available for dispersion, or redispersion, into the atmosphere by wind currents and automotive traffic, and air quality would be improved.

The net efficiency curves presented in Figure E-1 are equally applicable to mechanical sweepers or vacuum cleaners because, as is clear from equation 17, the effective cleaning rate, k, is the product of cleaning frequency and the equipment pick-up efficiency, which varies for individual equipment types.

It was assumed that equipment would be operated 16 hours per day. This obviously could be achieved by two 8-hour shifts, eight 2-hour shifts, or any other combination.

Actually, the necessary street cleaning area involved in the alternative providing the greatest water quality benefits was about 144,000 acres. For existing vacuum cleaners and the 95% removal efficiency required by water quality considerations, this was equivalent to a uniformly distributed 330 acres per machine. A more detailed facilities planning analysis would result in a quite different distribution, concentrating equipment where the street accumulations are greatest.

11.4.4 Land Treatment

COMMENTS

(pg 8-38)
The availability of 12,000 acres of land is a key issue that was not adequately addressed by the contractor. (O'Brien, EPA-I)

(Table 8-11)
Land costs at $2,000/acre are not reasonable, may be low by a factor of 5 or more. How would this affect cost/benefit analysis.

Note that land area required for Middle Charles and Upper Neponset plants are 7035 and 5675 acres, respectively. This should be clearly pointed out.

If land costs are low by a factor of 5, then land costs for Middle Charles and Upper Neponset land treatment plants sites would be $70.3 million and $56.75 million. This would increase total capital costs to $104.32 million and $84.93 million, respectively. These are more than double EMMA comparable costs. Will the capital cost differences negate land treatment under 77 FWPC Act Amendments (15% factor increase over conventional methods)?

Furthermore, I doubt if there are open land areas of the proper type available such that 7,035 and 5,675 acres could be devoted to land treatment. (Ikalainen, EPA-I)

(Table 8-12)
Land area required equals 12,710 acreas. If land application schemes with return flows to rivers were considered, effects on Dissolved Oxygen in the rivers would need to be investigated.

Other considerations involving land treatment are duration of effectiveness of land treatment sites. Do sites have a limited period for treatment. What would be the costs of abandoning existing treatment facilities? Has land area required for 5 month storage lagoons been considered in land treatment costs? A total of 2.58×10^4 acre feet of storage would be required at the end of the 5-month storage period. (Ikalainen, EPA-I)

RESPONSE

It can be verified by the Massachusetts Department of Agriculture that 20,000 to 30,000 acres of farm land in Massachusetts are removed permanently from agricultural production every year and that this trend has been constant for at least the last 20 years, so the question of adequate land availability is not a real issue. The EMMA Study (Vol. 5, page B4) fairly easily located potential land treatment sites in the EMMA study area totalling 10,521 acres, 90% of which were in the drainage basins of the Charles and Neponset River. Land costs in this report were based on actual sales prices for agricultural and forest lands during the period of this study.

Land areas included storage and pretreatment, buffer zones and treatment. See page H-11 for these breakdowns.

COMMENT

(pg 10-4)
It is not clear what future open space use can be realized if the land acquired must be used for land application. The implication is that sometime in the future the land will not be needed for treatment purposes. (O'Brien, EPA-I)

RESPONSE

Open space is space not occupied by housing, industry, or commercial enterprises. Future open space uses preserved by land application are, among others, agriculture and forestry.

COMMENTS

(Part 7)
The discussion of pretreatment on land application systems fails to mention the impact of industrial wastes on this option.
(O'Brien, EPA-I)

The need to accelerate pre-treatment programs for sewered industrial wastes was also recommended in the case studies. On June 26, 1978 EPA published its pre-treatment program regulations in the Federal Register. It is expected that specific requirements for 21 industrial categories will be adopted by December 1979. As authorized by the Clean Water Act of 1977, industries discharging into municipal sewers must meet these requirements within 3 years of their adoption. (Hanmer, EPA-I)

RESPONSE

This study attempted to consider each section of PL92-500 as an integral part of the whole rather than as a separate independent entity. Most, if not all, of the technological problems raised in the comments to this report would disappear if all sections of the Act were pursued as rigorously as is Section 301.

COMMENT

(Appendix H -- Table H-1)
Might be a question if this effluent and pollutant conc's would meet water quality standards. (Ikalainen, EPA-I)

RESPONSE

But a substantially lesser question than for the EMMA recommended AWT plants.

11.4.5 Miscellaneous Comments and Suggestions

COMMENT

When it is mentioned that certain water segments will be degraded, it should be followed by a list of the reasons for degradation, e.g. satellite plants, runoff, inadequate CSO control, etc. (O'Brien, EPA-I)

RESPONSE

This suggestion has been adopted.

COMMENT

(pg 7-3)
The use of one local technical journal article as being representative of what "AWT means in Boston" is not appropriate. AWT needs are decided on a case-by-case basis and can not be generalized.
(O'Brien, EPA-I)

RESPONSE

AWT needs may well be decided on a case-by-case basis, but in the Boston area each case has resulted in secondary treatment with phosphorus precipitation and filtration.

COMMENTS

(pg. 8-2)
Is alternative I.D.1 the 100 MGD expanded Deer Island capacity referenced here? Do all Category III alternatives include the $270 million EMMA CSO Plan? (O'Brien, EPA-I)

RESPONSE

All I.D. alternatives include the basic 100 mgd expanded Deer Island capacity. Alternative I.D.1 expands the Deer Island capacity further, while adding off-line storage capacity to the combined sewer systems (see Figure 8-7). All Category III alternatives do include the $270 million EMMA CSO Plan.

COMMENTS

(pg. 8-21)
It is not clear whether the column headed "2000 (ID)" represents the water quality objectives or the results of implementing alternative ID. Or are these one and the same? (O'Brien, EPA-I)

RESPONSE

The column headed "2000(ID)" represents water quality objectives.

COMMENT

(pg. 8-35)
Expand upon conditions under which Dissolved Oxygen will become the limiting criterion in the Inner Harbor. (Ikalainen, EPA-I)

RESPONSE

More precisely, the statement was that dissolved oxygen may become the limiting criterion in the Inner Harbor (emphasis added). One of the effects of the Charles River Estuarine Overflow Detention Facility is to collect combined sewer overflows from 1,070 acres now discharging to the Charles River Basin and transfer them downstream to Boston Inner Harbor. Because of the disparity between assumed coliform and BOD removals (90% and 20%, respectively) for these detention/chlorination facilities, it appears possible that BOD removals can be largely offset by the discharge point relocations although, within the limited context described on page 8-35, net coliform removals could be adequate for the Inner Harbor. It should be noted that this possibility (adequate coliform removals) disappears when the chlorination efficiency assumption is discounted.

COMMENT

(pg. 9-7)
It is not clear whether or not the costs of alternative IA includes rehabilitation costs. For clarify, we suggest the following changes to Table 9-2:

I.D. be changed to I.D.1
I.D.2/4a be changed to I.D.2-4a. (O'Brien, EPA-I)

RESPONSE

Rehabilitation costs were not included in the draft version of this report. They are now included.

I.D. and I.D.1 are not synonymous (see above). The nomenclature I.D.2/4a has been changed in this report to I.D.2&4a, which indicates Alternative I.D.: options 2 and 4a. The nomenclature: I.D. 2&4 a-d now indicates Alternative I.D. options 2 and 4a,b,c and d. The precise descriptions of these alternatives and options are included in Table 9-2.

COMMENT

(pg. 10-1, Second paragraph)
Reference to (Horowitz and Bazel) is not in the list of references.
(Ikalainen, EPA-I)

RESPONSE

This reference is now included. It is titled "An Analysis of Planning for Advanced Waste Treatment (AWT)" and is the final report to EPA (Office of Planning and Evaluation) under Contract No. 68-01-4338 (July 1977). This report should be mandatory reading for all water quality management planners; it illuminates the widespread flaws in the nation's 303(e) planning process. After such an exemplary analysis, however, the recommendation by Horowitz and Bazel that EPA should petition the Congress for the elimination of Section 303, on the grounds that its implementation has been so inadequate, is an incomprehensibly perverse reaction. Rather, since Section 303 provides the only basis in PL92-500 for scientific analysis and planning development, its rigorous application and enforcement provide the only believable route to achievement of the national water quality objective and goals of the Act.

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APPENDIX A1

COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION
DIVISION OF WATER POLLUTION CONTROL

RULES AND REGULATIONS FOR THE ESTABLISHMENT OF MINIMUM WATER QUALITY STANDARDS AND FOR THE PROTECTION OF THE QUALITY AND VALUE OF WATER RESOURCES

(1974)

The Division of Water Pollution Control, acting under the authority of Sections 27 (5) and (12) of Chapter 21 of the General Laws and other Acts relating thereto enabling, hereby adopts and establishes the following Rules and Regulations to restore, maintain and enhance the quality of the waters of the Commonwealth; to designate the uses for which the various waters of the state shall be maintained and protected; to prescribe the water quality standards required to sustain the designated uses; and to prescribe regulations necessary for implementing, achieving and maintaining the prescribed water quality.

Filed with Secretary of State May 2, 1974

RULES AND REGULATIONS
FOR THE ESTABLISHMENT OF
MINIMUM WATER QUALITY STANDARDS
AND FOR THE PROTECTION OF THE
QUALITY AND VALUE OF WATER RESOURCES

Regulation I - Definitions

The terms used in the following regulations are defined as follows:

1. Appropriate Treatment - means that degree of treatment required for the waters of the Commonwealth to meet their assigned classifications or any terms, conditions or effluent limitations established as part of any permit to discharge issued under the provisions of the Massachusetts Clean Waters Act, or any effluent standard or prohibition established by the Division under authority of Section 27 (6) of the Massachusetts Clean Waters Act.

2. Division - means the Commonwealth of Massachusetts, Division of Water Pollution Control.

3. Person - means any agency or political subdivision of the Commonwealth, public or private corporation or authority, individual, partnership or association, or other entity, including any officer of a public or private agency or organization, upon whom a duty may be imposed by or pursuant to any provision of Sections 26-53 inclusive, of Chapter 21 of the General Laws.

4. Sewage - means the water-carried waste products or discharges from human beings, sink wastes, wash water, laundry waste and similar so-called domestic waste.

5. The "Waters of the Commonwealth" and "Waters" - means all waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, coastal waters and ground waters.

6. Fresh Waters - means waters not subject to the rise and fall of the tide.

7. Salt Waters - means all waters subject to the rise and fall of the tide.

8. Cold Water Stream - means a stream capable of sustaining a population of cold water fish, primarily Salmonids.

9. Seasonal Cold Water Stream - means a stream which is only capable of sustaining cold water fish during the period of September 15 through June 30.

10. Waste Treatment Facility - processes, plants or works, installed for the purpose of treating, neutralizing, stabilizing or disposing of wastewater.

11. Pollutant - means any element or property of sewage, agricultural, industrial, or commercial waste, run-off, leachate, heated effluent or other matter in whatever form and whether originating at a point or nonpoint source, which is or may be discharged, drained or otherwise introduced into the waters of the Commonwealth.

12. Discharge - means the flow or release of any pollutant into the waters of the Commonwealth.

13. Wastewater - means sewage, liquid or water-carried waste from industrial, commercial, municipal, private or other sources.

14. Zone of Passage - means a continuous water route of the volume, area and quality necessary to allow passage of free-swimming and drifting organisms with no significant effect produced on the population.

Regulation II - Water Quality Standards

1 - The Water Quality Standards adopted by the Massachusetts Division of Water Pollution Control on March 3, 1967 and filed with the Secretary of State on March 6, 1967 are hereby repealed, except that existing "River Basin Classifications" based on the 1967 Standards will remain in full force and effect until reclassified in accordance with the following standards.

2 - To achieve the objectives of the Massachusetts Clean Waters Act and the Federal Water Pollution Control Act Amendments of 1972 and to assure the best use of the waters of the Commonwealth the following standards are adopted and shall be applicable to all waters of the Commonwealth or to different segments of the same waters.

3 - Fresh Water Standards

Class A - These waters are designated for use as sources of public water supply in accordance with the provisions of Chapter 111 of the General Laws.

Water Quality Criteria

Item		Criteria
1.	Dissolved oxygen	Not less than 75% of saturation during at least 16 hours of any 24 hour period and not less than 5 mg/l at any time. For cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l during the season.
2.	Sludge deposits-solid refuse-floating solids-oil-grease-scum	None allowable
3.	Color and turbidity	None other than natural origin.
4.	Total Coliform bacteria per 100 ml.	Not to exceed an average value of 50 during any monthly sampling period.
5.	Taste and odor	None other than of natural origin.
6.	pH	As naturally occurs.
7.	Allowable temperature increase	None other than of natural origin.
8.	Chemical constituents	None in concentrations or combinations which would be harmful or offensive to humans, or harmful to animal or aquatic life.
9.	Radioactivity	None other than that occurring from natural phenomena.

Class B - These waters are suitable for bathing and recreational purposes, water contact activities, acceptable for public water supply with treatment and disinfection, are an excellent fish and wildlife habitat, have excellent aesthetic values and are suitable for certain agricultural and industrial uses.

Item		Criteria
1.	Dissolved oxygen	Not less than 75% of saturation during at least 16 hours of any 24 hour period and not less than 5 mg/l at any time. For cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l during the season.
2.	Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3.	Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4.	Coliform bacteria per 100 ml	Not to exceed an average value of 1000 nor more than 1000 in 20% of the samples.
5.	Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish.
6.	pH	6.5 - 8.0
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold

		water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8.	Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human, or harmful to animal or aquatic life or any water use specifically assigned to this class.
9.	Radioactivity	None in concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class B1 - The use and criteria for Class B1 shall be the same for Class B with the exception of the dissolved oxygen requirement which shall be as follows for this class:

Item		Criteria
1.	Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24 hour period, nor less than 3 mg/l at any time. For seasonal cold water fisheries at least 6 mg/l must be maintained during the season.

Class C - These waters are suitable for recreational boating and secondary water contact recreation, as a suitable habitat for wildlife and fish indigenous to the region, for certain agricultural and industrial uses, have good aesthetic values, and under certain conditions are acceptable for public water supply with treatment and disinfection.

Item		Criteria
1.	Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24 hour period, nor less than 3 mg/l at any time. For, seasonal cold water fisheries at least 6 mg/l must be maintained during the season.
2.	Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3.	Color and turbidity	None allowable in such concentrations that would impair any uses specifically assigned to this class.
4.	Coliform bacteria	None in such concentrations that would impair any usages specifically assigned to this class, see Note 1.
5.	Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class, and none that would cause taste and odor in edible fish.
6.	pH	6.0 - 8.5
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case exceed 80°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8.	Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human life, or harmful to animal or aquatic life or any other water use specifically assigned to this class.
9.	Radioactivity	None in such concentrations or combinations in excess of the limit specified by the United States Public Health Service Drinking Water Standards.

Note 1 - no bacteria limit has been placed on Class "C" waters because of the urban runoff and combined sewer problems which have not yet been solved. In waters of this class not subject to urban runoff or combined sewer discharges the bacterial quality of the water should be less than an average of 5,000 coliform bacteria/100 ml during any monthly sampling period. It is the objective of the Division to eliminate all point and non-point sources of pollution and to impose bacterial limits on all waters.

Clas [illegible]1 - The use and criteria for Class C1 shall be the same as for Class C with the exception of the dissolved oxygen (and temperature) requirements which shall be as follows for this Class:

Item		Criteria
1.	Dissolved oxygen	Not less than 2 mg/l at any time.

Salt Water Standards

Class SA - These are waters of the highest quality and are suitable for any high water quality use including bathing and other water contact activities. These waters are suitable for approved shellfish areas and the taking of shellfish without depuration, have the highest aesthetic value and are an excellent fish and wildlife habitat.

Water Quality Criteria

Item		Criteria
1.	Dissolved oxygen	Not less than 6.5 mg/l at any time.
2.	Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3.	Color and turbidity	None in such concentrations that will impair any uses specifically assigned to this class.
4.	Total Coliform bacteria per 100 ml	Not to exceed a median value of 70 and not more than 10% of the samples shall ordinarily exceed 230 during any monthly sampling period.
5.	Taste and odor	None allowable.
6.	pH	6.8 - 8.5
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8.	Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same or impair the waters for any other uses.
9.	Radioactivity	None in concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class SB - These waters are suitable for bathing and recreational purposes including water contact sports and industrial cooling, have good aesthetic values, are an excellent fish habitat and are suitable for certain shell fisheries with depuration (Restricted Shellfish Areas).

Item		Criteria
1.	Dissolved oxygen	Not less than 5.0 mg/l at any time.
2.	Sludge deposits-solid refuse-floating solids-oils-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing adequate treatment. For oil and grease of petroleum origin, the maximum allowable concentration is 15 mg/l.
3.	Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4.	Total Coliform bacteria per 100 ml	Not to exceed an average value of 700 and not more than 1000 in more than 20% of the samples.
5.	Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6.	pH	6.8 - 8.5
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8.	Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the water for any other use.
9.	Radioactivity	None in such concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class SC - These waters are suitable for aesthetic enjoyment, for recreational boating, as a habitat for wildlife and common food and game fishes indigenous to the region, and are suitable for certain industrial uses.

Item		Criteria
1.	Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24-hour period nor less than 3 mg/l at any time.
2.	Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3.	Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4.	Total Coliform bacteria	None in such concentrations that would impair any uses specifically assigned to this class. See Note 2.
5.	Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6.	pH	6.5 - 8.5
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8.	Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe for fish or shellfish or their propagation, impair the palatability of same, or impair the water for any other use.
9.	Radioactivity	None in such concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Note 2: no bacteria limit has been placed on Class "SC" waters because of the urban runoff and combined sewer problems which have not yet been solved. In waters of this class not subject to urban runoff or combined sewer discharges, the bacterial quality of the water should be less than an average of 5,000 coliform bacteria/100 ml during any monthly sampling period. It is the objective of the Division to eliminate all point and non-point sources of pollution and to impose bacterial limits on all waters.

Regulation III - General Provisions

1. It is recognized that certain waters of the Commonwealth possess an existing quality which is better than the standards assigned thereto.

   A. Except as otherwise provided herein, no new discharge of wastewater will be permitted into any stream, river or tributary upstream of the most upstream discharge of wastewater from a municipal waste treatment facility or municipal sewer discharging wasts requiring appropriate treatment as determined by the Division. Any person having an existing wastewater discharge shall be required to cease such discharge and connect to a municipal sewer unless it is shown by said person that such connection is not available or feasible. Existing discharges not connected to a municipal sewer will be provided with the highest and best practical means of waste treatment to maintain high water quality. New discharges from a municipal waste treatment facility into such waters will be permitted provided that such discharge is in accordance with a plan developed under the provisions of Section 27(10) of Chapter 21 of the General Laws (Massachusetts Clean Waters Act) which has been the subject of a Public Hearing and approved by the Division. The discharge of industrial liquid coolant wastes in conjunction with the public and private supply of heat or electrical power may be allowed provided that a permit has been issued by the Division and that such discharge is in conformance with the terms and conditions of the permit and in conformance with the water quality standards of the receiving waters.

   B. Except as otherwise provided herein, no new discharge of wastewater will be permitted in Class SA or SB waters. Any person having an existing discharge of wastewater into Class SA or SB waters will be required to cease said discharge and to connect to a municipal sewer unless it is shown by said person that such connection is not available or feasible. Existing discharges not connected to a municipal sewer will be provided with the highest and best practical means of waste treatment to maintain high water quality. New discharges from a waste treatment facility into such waters will be permitted provided such discharge is in accordance with a plan developed under the provisions of Section 27(10) of Chapter 21 of the General Laws (Massachusetts Clean Waters Act) which has been the subject of a Public Hearing and approved by the Division. The discharge of industrial coolant wastes in conjunction with the public and private supply of heat or electrical power may be allowed provided that a permit has been issued by the Division and that such discharge is in conformance with the terms and conditions of the permit and in conformance with the Water Quality Standards of the receiving waters.

2. The latest edition of the Federal publication "Water Quality Criteria" will be considered in the interpretation and application of bioassay results.

3. The latest edition of Standard Methods for Examination of Water and Wastewater, American Public Health Association, will be followed in the collection, preservation and analysis of samples. Where a method is not given in the standards methods, the latest procedures of the American Society for Testing Materials (ASTM) will be followed.

4. The average minimum consecutive 7-day flow to be expected once in 10 years shall be used in the interpretation of the standards.

5. In the discharge of waste treatment plant effluents into receiving waters, consideration shall be given both in time and distance to allow for mixing of effluent and stream. Such distances required for complete mixing shall not effect the water use classifications' adopted by the Division. However, a zone of passage must be provided wherever mixing zones are allowed.

6. There shall be no new discharges of nutrients into lakes or ponds. In addition, there shall be no new discharge of nutrients to tributaries of lakes or ponds that would encourage eutrophication or growth of weeds or algae in these lakes or ponds.

7. Any existing discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be treated to remove such nutrients to the maximum extent technically feasible.

8. These Water Quality Standards do not apply to conditions brought about by natural causes.

9. All waters shall be substantially free of products that will (1) unduly affect the composition of bottom fauna, (2) unduly affect the physical or chemical measure of the bottom, (3) interfere with the spawning of fish or their eggs.

10. No person shall discharge any pollutants into any waters of the Commonwealth which shall cause a violation of the standards.

11. A person shall submit to the Division for approval all plans for the construction of or addition to any waste treatment facility and no such facility may be constructed, modified or enlarged without such approval.

12. Cold water and seasonal cold water streams shall be those listed by the Massachusetts Division of Fisheries and Game.

13. Whoever violates any provision of these regulations shall (a) be fined not less than two thousand five hundred dollars nor more than twenty-five thousand dollars for each day of such violation or its continuance, or by imprisonment for not more than one year, or by both; or (b) shall be subject to a civil penalty not to exceed ten thousand dollars per day of such violation, which may be assessed in an action brought on behalf of the Commonwealth in any court of competent jurisdiction, pursuant to Section 42 of Chapter 21 of the Massachusetts General Laws.

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14. The Division and its duly authorized employees shall have the right to enter at all reasonable times into or on, any property, public or private, for the purpose of inspecting and investigating conditions relating to pollution or possible pollution of any waters of the Commonwealth, pursuant to Section 40 of Chapter 21 of the Massachusetts General Laws.

15. If any regulation, paragraph, sentence, clause, phrase or word of these regulations shall be declared invalid for any reason whatsoever, that decision shall not affect any other portion of these regulations, which shall remain in full force and effect and to this end the provisions of these regulations are hereby declared severable.

Appendix A2

COMMONWEALTH OF MASSACHUSETTS

WATER RESOURCES COMMISSION

DIVISION OF WATER POLLUTION CONTROL

MASSACHUSETTS WATER QUALITY STANDARDS

Revised: April 7, 1978

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Commonwealth of Massachusetts

Water Resources Commission

Division of Water Pollution Control

WATER QUALITY STANDARDS

PART 1 GENERAL PROVISIONS

Regulation 1.1 Title. These regulations shall be known as the "Massachusetts Water Quality Standards."

Regulation 1.2 Organization of Standards. The Massachusetts Water Quality Standards are comprised of five units: General Provisions (Part 1), Application of Standards (Part 2) Water Quality Criteria (Part 3), Antidegradation Provisions (Part 4) and Basin Classifications and Maps (Part 5).

Regulation 1.3 Authority. The Massachusetts Water Quality Standards are adopted by the Division pursuant to the provisions of M.G.L. c.21, §27 and other enabling acts relating thereto.

Regulation 1.4 Purpose. The Massachusetts Act charges the Division with the duty and responsibility to enhance the quality and value of the water resources of the Commonwealth and directs the Division to take all action necessary or appropriate to secure to the Commonwealth the benefits of the Federal Act. The objective of the Federal Act is the restoration and maintenance of the chemical, physical and biological integrity of the Nation's waters. As a goal towards this objective, the Federal Act requires, by 1983, the achievement of water quality which provides for the protection and propagation of fish, sh[illegible]ish and wildlife and provides for recreation in and on the water wherever attainable. To achieve the foregoing requirements the Division has adopted the Massachusetts Water Quality Standards which designate the uses for which the various waters of the Commonwealth shall be enhanced, maintained and protected; which prescribe the water quality criteria required to sustain the designated uses; and which contain regulations necessary to achieve the designated uses and maintain existing water quality including, where appropriate, the prohibition of discharges.

Regulation 1.5 Definitions. As used in these standards, the following words have the following meanings:

Artificial conditions - Those conditions resulting from human alteration of the chemical, physical or biological integrity of waters.

Beneficial use - Any use not impairing the most sensitive use designated in the classification tables contained in Part 5; except that in no case shall the assimilation or transport of pollutants be deemed a beneficial use.

Cold water fishery - Waters whose quality is capable of sustaining a year-round population of cold water trout (salmonidae).

Division - The Massachusetts Division of Water Pollution Control, as established by General Laws c.21, §26.

Discharge - Any addition of any pollutant to the waters of the Commonwealth.

EPA - The United States Environmental Protection Agency.

Federal Act - The Federal Water Pollution Control Act, as amended, 33 U.S.C. §§1251, et seq.

Massachusetts Act - The Massachusetts Clean Waters Act, as amended, General Laws, c.21, §§26-53, inclusive.

Pollutant - Any element or property of sewage, agricultural, industrial or commercial waste, runoff, leachate, heated effluent, or other matter, in whatever form and whether originating at a point or major nonpoint source, which is or may be discharged, drained or otherwise introduced into any sewerage system, treatment works or waters of the Commonwealth.

Primary contact recreation - Any recreation or other water use, such as swimming and water skiing, in which there is prolonged and intimate contact with the water sufficient to constitute a health hazard.

Seasonal cold water fishery - Waters whose quality is capable of sustaining only an extremely limited cold water population on a year-round basis, with cold-water fish in these streams provided largely by stocking.

Secondary contact recreation - Any recreation or other water use in which contact with the water is either incidental or accidental, such as fishing, boating and limited contact incident to shoreline activities.

Segment - A finite portion of a water body established by the Division for the purpose of classification.

Warm water fishery - Waters whose quality is not capable of sustaining a year-round cold water or seasonal cold water fishery.

Waters of the Commonwealth - All waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries and coastal waters, but not including groundwaters.

Regulation 1.6 Severability. If any provision of these standards is held invalid, the remainder of these standards shall not be affected thereby.

Regulation 1.7 Repealer. The "Rules and Regulations for the Establishment of Minimum Water Quality Standards and for the Protection of the Quality and Value of Water Resources" filed with the Secretary of the Commonwealth on May 2, 1974 and the "River Basin Classifications" filed with the Secretary of the Commonwealth on July 21, 1967 are hereby repealed, except that all permits, orders, determinations or other actions of the Division, based upon such standards and river basin classifications, and any court actions seeking to enforce such standards, permits, orders and determinations shall remain in full force and effect until modified, amended, revoked or reissued by the Division and/or the courts of the Commonwealth, as appropriate.

Regulation 1.8 Effective Date. These standards shall become effective upon publication by the Secretary of the Commonwealth pursuant to the provisions of G.L. c.30A, §6.

PART 2 APPLICATION OF STANDARDS

Regulation 2.1 Establishment of Effluent Limitations. In regulating discharges of pollutants to waters of the Commonwealth, the Division will limit or prohibit such discharges to insure that the water quality standards of the receiving waters will be maintained or attained. The determination by the Division of the applicable level of treatment for an individual discharger will be made in the establishment of effluent limitations in the individual discharge permits. In establishing such effluent limitations, the Division must consider natural background conditions, protect existing downstream uses, and not interfere with the maintenance and attainment of beneficial uses in downstream waters. Toward this end, the Division may provide a reasonable margin of safety to account for any lack of knowledge concerning the relationship between the pollutants being discharged and their impact on the quality of the receiving waters.

Municipal discharges to inland waters and industrial discharges to all waters must provide minimum of secondary treatment or its industrial waste equivalent. In coastal and marine waters, municipal dischargers must provide a minimum of primary treatment plus disinfection. The above minimum treatment requirements will be increased where necessary to satisfy other state and federal laws and regulations or to achieve the water quality assigned in these regulations, whichever is the most stringent.

As used in this section, "secondary treatment" is that process or group of processes capable of removing from untreated wastewater a minimum of 85% of the 5 day biochemical oxygen demand and suspended solids, and virtually all floating and settleable solids, followed by disinfection. The "equivalent" treatment for industrial waste may generally be defined as that process or group of processes achieving maximum practicable removal of solids, oils, grease, acids, alkalis, toxic materials, bacteria, taste and odor causing materials, color and other objectionable constituents contained in untreated waste to produce an effluent equivalent to that obtained from secondary treatment of sewage or the effluent from the most efficient treatment facilities in current use for any specific category of industrial waste. Disinfection of treated effluent may be discontinued between October 15 and April 1 at the discretion of the Division. At the discretion of the Division, nitrification and/or phosphorus removal processes at municipal sewage treatment facilities may be seasonally discontinued.

Regulation 2.2 Mixing Zones. In applying these standards, the Division may recognize, where appropriate, a limited mixing zone or zone of initial dilution on a case-by-case basis. The location, size and shape of these zones shall provide for the maximum protection aquatic resources. At a minimum, mixing zones must:

a) Meet the criteria for aesthetics;

b) Be limited to an area or volume that will minimize interference with the designated uses or established community of aquatic life in the segment:

c) Allow an appropriate zone of passage for migrating fish and other organisms; and

d) Not result in substances accumulating in sediments, aquatic life or food chains to exceed known or predicted safe exposure levels for the health of humans or aquatic life.

Regulation 2.3 Hydrologic Conditions. The Division will determine the most severe hydrologic condition at which water quality standards must be met. In classifying the inland waters of the Commonwealth and in applying these standards to such waters, the critical low flow condition at and above which these standards must be met is the average minimum consecutive seven day flow to be expected once in ten years, unless otherwise stated by the Division in these standards. In artificially regulated waters, the critical low flow will be established by the Division through agreement with the Federal, state or private interest controlling the flow. The minimum flow established in such agreement will become the critical low flow under this section for those waters covered by the agreement.

Regulation 2.4 Procédures for Sampling and Analysis. For the purpose of collecting, preserving and analyzing samples in connection with these water quality standards, the fourteenth edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association, or Methods for Chemical Analysis of Water and Wastes published by the U.S. Environmental Protection Agency should be used. Where a method is not given in these publications, the latest procedures of the American Society for Testing Materials (ASTM) shall be used, or any other equivalent method approved by the Director.

PART 3 MINIMUM WATER QUALITY CRITERIA AND ASSOCIATED USES

Regulation 3.1 Description of Contents. This part sets forth the Classes to be used by the Division in classifying the waters of the Commonwealth according to the uses for which the waters shall be enhanced, maintained and protected. For each class, the most sensitive beneficial uses are identified and minimum criteria for water quality in the water column are established. The minimum criteria in Reg. 3.4 have been developed by applying the criteria contained in the EPA publication Quality Criteria for Water (EPA-440/9-76-023) to account for local conditions including, but not limited to:

a) The characteristics of the biological community

b) Temperature, weather and flow characteristics, and

c) Synergistic and antagonistic effects of combinations of pollutants.

Regulation 3.2 Coordination with Federal Criteria. The Division will use the EPA publication entitled Quality Criteria for Water, EPA-440/9-76-023 as guidance in establishing case-by-case discharge limits for pollutants not specifically listed in these standards but included under the heading "Other Constituents" in Regulation 3.4, for identifying bioassay application factors and for interpretations of narrative criteria. Where the minimum criteria specifically listed by the Division in this part differ from those contained i the federal criteria, the provisions of the specifically listed criteria in these standards shall apply.

Regulation 3.3 Classes and Designated Uses. The waters of the Commonwealth will be assigned to one of the classes listed below. Each class is defined by the most sensitive, and therefore governing, uses which it is intended to protect. The classes are:

Classes for Inland Waters

Class A - Waters assigned to this class are designated for use as a source of public water supply.

Class B - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for primary and secondary contact recreation.

Class C - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for secondary contact recreation.

Classes for Coastal and Marine Waters

Class SA - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting without depuration in approved areas.

Class SB - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting with depuration (Restricted Shellfish Areas).

Class SC - Waters assigned to this class are designated for the protection and propagation of fish, other aquatic life and wildlife; and for secondary contact recreation.

Regulation 3.4 Minimum Criteria. The following minimum criteria are adopted and shall be applicable to all waters of the Commonwealth.

A. These minimum criteria are applicable to all waters of the Commonwealth, unless criteria specified for individual classes are more stringent.

Parameter	Criteria
1. Aesthetics	All waters shall be free from pollutants in concentrations or combinations that: a) Settle to form objectionable deposits; b) Float as debris, scum or other matter to form nuisances; c) Produce objectionable odor, color, taste or turbidity; or d) Result in the dominance of nuisance species.

2. Radioactive Substances	Shall not exceed the recommended limits of the United States Enviornmental Protection Agency's National Drinking Water Regulations.
3. Tainting Substances	Shall not be in concentrations or combinations that produce undesirable flavors in the edible portions of aquatic organisms.
4. Color, Turbidity, Total Suspended Solids	Shall not be in concentrations or combinations that would exceed the recommended limits on the most sensitive receiving water use.
5. Oil and Grease	The water surface shall be free from floating oils, grease and petrochemicals and any concentrations or combinations in the water column or sediments that are aesthetically objectionable or deleterious to the biota are prohibited. For oil and grease of petroleum origin the maximum allowable discharge concentration is 15 mg/l.
6. Nutrients	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
7. Other Constituents	Waters shall be free from pollutants in concentrations or combinations that a) Exceed the recommended limits on the most sensitive receiving water use; b) Injure, are toxic to, or produce adverse physiological or behavioral responses in humans or aquatic life; or c) Exceed site-specific safe exposure levels determined by bioassay using sensitive resident species.

B. Inland Waters - the following additional minimum criteria are applicalbe to inland water classifications.

For Class A waters:

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°c) in warm water fisheries or 68°F (20°c) in cold water fisheries nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°c).
3. pH	As naturally occurs.

4. Total Coliform Bacteria	Shall not exceed a log mean for a set of samples of 50 per 100 ml during any monthly sampling period.
5. Turbidity	None other than of natural origin.
6. Total Dissolved Solids	Shall not exceed 500 mg/l.
7. Chlorides	Shall not exceed 250 mg/l.
8. Sulfates	Shall not exceed 250 mg/l.
9. Nitrate	Shall not exceed 10 mg/l as nitrogen.

For Class B waters:

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°c) in warm water fisheries or 68°F (20°c) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°c).
3. pH	Shall be in the range of 6.5 - 8.0 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 200 per 100 ml, nor shall more than 10% of the total samples exceed 400 per 100 ml during any monthly sampling period, except as provided in Regulation 2.1

For Class C waters:

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°c) in warm water fisheries or 68°F (20°c) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°c).

3. pH	Shall be in the range of 6.5-9.0 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 1000 per 100 ml, nor shall more than 10% of the total samples exceed 2,500 per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.

C. Coastal and Marine Waters - the following additional minimum criteria are applicable to coastal and marine waters.

For Class SA waters:

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 6.0 mg/l.
2. Temperature	None except where the increase will not exceed the recommended limits on the most sensitive water use.
3. pH	Shall be in the range of 6.5-8.5 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Total Coliform Bacteria	Shall not exceed a median value of 70 MPN per 100 ml and not more than 10% of the samples shall exceed 230 MPN per 100 ml in any monthly sampling period.

For Class SB waters:

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 6.0 mg/l.
2. Temperature	None except where the increase will not exceed the recommended limits on the most sensitive water use.
3. pH	Shall be in the range of 6.5-8.5 and not more than 0.2 units outside of the naturally occurring range.
4. Total Coliform Bacteria	Shall not exceed a median value of 700 MPN per 100 ml and not more than 20% of the samples shall exceed 1000 MPN per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.

For Class SC waters:

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 6.0 mg/l.
1. Temperature	None except where the increase will not exceed the recommended limits on the most sensitive water use.
3. pH	Shall be in the range of 6.5-8.5 standard units and not more than 0.2 units outside the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 1000 MPN per 100 ml, nor shall more than 10% of the total samples exceed 2500 MPN per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.

PART 4 ANTIDEGRADATION PROVISIONS

Regulation 4.1 Protection of Existing Uses. In all cases, from and after the date these regulations become effective, the quality of the waters of the Commonwealth shall be maintained and protected to sustain existing beneficial uses.

Regulation 4.2 Protection of High Quality Waters. From and after the date these regulations become effective, waters designated by the Division in Regulation 5.5 whose quality is or becomes consistantly higher than that quality necessary to sustain the national goal uses shall be maintained at that higher level of quality unless limited degradation is authorized by the Division. Limited degradation may be allowed by the Division as a variance from this regulation as provided in Section 4.6.

Regulation 4.3 Protection of Low Flow Waters. Certain waters will be designated by the Division in Regulation 5.5 of these standards for protection under this section due to their inability to accept pollutant discharges. New or increased discharges of pollutants to waters so designated are prohibited unless a variance is granted by the Division as provided in Regulation 4.6.

Regulation 4.4 National Resource Waters. Waters which constitute an outstanding national resource as determined by their outstanding recreational, ecological and/or aesthetic values shall be preserved. These waters shall be designated for preservation by the Division in Regulation 5.5 of these standards. Waters so designated may not be degraded and are not subject to a variance procedure. New discharges of pollutants to such waters are prohibited. Existing discharges shall be eliminated unless the discharger is able to demonstrate that:

a) Alternative means of disposal are not reasonably available or feasible; and

b) The discharge will not affect the quality of the water as a national resource.

Regulation 4.5 Control of Eutrophication. The discharge of nutrients, primarily phosphorus or nitrogen, to waters of the Commonwealth will be limited or prohibited by the Division as necessary to prevent excessive eutrophication of such waters. There shall be no new or increased discharges of nutrients into lakes and ponds, or tributaries thereto. Existing discharges containing nutrients which encourage eutrophication or growth of weeds or algae shall be treated. Activities which may result in non-point discharges of nutrients shall be conducted in accordance with the best management practices reasonably determined by the Division to be necessary to preclude or minimuze such discharges of nutrients.

Regulation 4.6 Variances. A variance to authorize a discharge in water designated for protection under regulation 4.2 may be allowed by the Division where the applicant demonstrates that:

1) The proposed degradation will not result in water quality less than specified for the class; and

2) The adverse economic and social impacts specifically resulting from imposition of controls more stringent than secondary treatment to maintain the higher water quality are substantial and widespred in comparision to other economic factors and are not warranted by a comparison of the economic, social and other benefits to the public resulting from maintenance of the higher quality water.

In addition to the above, the applicant for a variance to authorize a discharge into waters designated for protection under Regulation 4.3 must demonstrate that:

3) Alternative means of disposal are not reasonably available or feasible.

In any proceeding where such variance is at issue, the Division shall circulate a public notice in accordance with the procedures set forth in G.L. c30A, §3. Said notice shall state that a variance is under consideration by the Division, and indicate the Director's tentative determination relative thereto. To the extent feasible, the variance proceeding shall be conducted as part of any pending discharge permit proceedings pursuant to G.L. c.21, §43. In any variance procedure, the burden of proof relative to justifying the variance shall be on the party requesting the variance. Any variance granted pursuant to this regulation shall not extend beyond the expiration date of the permit.

PART 5 BASIN CLASSIFICATIONS AND MAPS

Regulation 5.1 Description of Contents. This part sets forth the procedures and guidelines the Division must follow in classifying the waters of the Commonwealth, and the classifications themselves. The procedural rules for classifying are contained in Regulations 5.2 through 5.4. Regulation 5.5 contains maps and tabulations identifying the assignment by the Division of each segment to one of the classes set forth in Part 3.3 of these Standards, the designation of uses and associated criteria for that segment and the imposition of special limitations in regulations 4.2, 4.3 and 4.4 to that segment.

Regulation 5.2 Designation of Uses. In determining the appropriate classification for a particular water, the Division must fulfill its statutory mandate as set forth in Regulation 1.4 of these standards. Wherever attainable, the Division shall designate the national goal uses of protection and propagation of fish, shellfish, aquatic life and wildlife and recreation in and on the waters in classifying the waters of the Commonwealth. In determining whether the national goal uses are attainable for a given water, the Division has considered limitations imposed by natural conditions, irreversible artificial conditions and the availability of feasible technological treatment methods and designated the optimum number of beneficial uses attainable in the circumstances.

Regulation 5.3 Other Applicable Standards. Waters classified by the Division in this part may be subject to additional restrictions pursuant to federal or Massachusetts statutes and regulations. Where such additional restrictions are known they are noted in the classifications in this part. Where these restrictions impose requirements more stringent than required under the Massachusetts or Federal Acts, e.g. public health restrictions relative to water supplies, such restrictions shall be considered and applied by the Division in classifying the waters to the extent authorized in the Massachusetts Act.

Regulation 5.4 Fisheries Designations. For inland waters certain specific criteria become applicable on the basis of their designation as a particular type of fishery. Therefore, inland segments are designated as cold water, seasonal cold water or warmwater fisheries. In seasonal cold water fisheries criteria for cold water fisheries apply during the period of September 15 through June 30 annually, and criteria for warm water fisheries apply at all other times.

Where the Division determines that natural conditions prevent the attainment of water quality capable of supporting a warm water fishery, a use designation of aquatic life has been made. In each segment so designated in Regulation 5.5, the criteria for a warm water fishery apply for all constituents except those affected by the natural condition, which constituents shall be governed by the most sensitive resident species as determined by the Director in consultation with the Massachusetts Division of Fisheries and Game.

Regulation 5.5 Classifications. For the purpose of applying the Massachusetts Water Quality Standards, the waters of the Commonwealth are hereby classified as shown in the following tables which are a part of these regulations. Columns 1 and 2 of the tables describes the segment. Column 3 identifies the applicable classification of the segment. Column 4 identifies the use or uses for which the segment is designated; (P&S) means primary and secondary contact recreation, (Sn) means seasonal fishery, (O) means open shellfishing, (R) means restricted shellfishing. Column 5 identifies the applicable provisions of Part 4 and Regulatin 5.3.

Segments and their classifications are shown on maps for general orientation. In case of inconsistancy between the tables and the maps, the data contained in the table shall control.

APPENDIX B

POPULATIONS, SEWERAGE SERVICES AND LAND USE DISTRIBUTIONS FOR STUDY AREA COMMUNITIES

MUNICIPAL DATA FORMAT

Town/City: Arlington

Total Area (acres) 3,571

	Year: 1970	2000
Population:	53,557	54,012
A. Sewer Service (population)		
1. Separate Sanitary	53,557	54,012
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	53,557	54,012
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,749	2,709
b. Commercial	166	104
c. Industrial	99	123
d. Other		
e. Total Storm Sewer Area	3,014	2,936
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	22	22
2. Forest	194	195
3. Wetlands	217	218
4. Mining/Disposal		
5. Recreation	124	200
6. Construction		
7. Total Non-Point Area	557	635

MUNICIPAL DATA FORMAT

Town/City: Bellingham

Total Area (acres) 12,070

	Year: 1970	2000
Population:	13,967	17,280
A. Sewer Service (population)		
1. Separate Sanitary	0	13,823
2. Combined	0	0
3. Unsewered	13,967	3,457
4. Total Sewered Population	0	13,823
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,756	2,318
b. Commercial	370	507
c. Industrial	606	679
d. Other	0	0
e. Total Storm Sewer Area	2,732	3,504
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	1,729	1,584
2. Forest	6,456	5,916
3. Wetlands	692	634
4. Mining/Disposal	346	317
5. Recreation	115	115
6. Construction		
7. Total Non-Point Area	9,338	8,566

MUNICIPAL DATA FORMAT

Town/City: Belmont

Total Area (acres) 2,982

	Year: 1970	2000
Population:	28,314	27,993
A. Sewer Service (population)		
1. Separate Sanitary	24,350	27,993
2. Combined	0	0
3. Unsewered	3,964	0
4. Total Sewered Population	24,350	27,993
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,947	1,877
b. Commercial	337	267
c. Industrial	54	142
d. Other	0	0
e. Total Storm Sewer Area	2,338	2,286
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	83	89
2. Forest	366	396
3. Wetlands	62	67
4. Mining/Disposal	8	9
5. Recreation	125	135
6. Construction		
7. Total Non-Point Area	644	696

MUNICIPAL DATA FORMAT

Town/City: Boston
(Drainage to basin, downstream of B.U. bridge)

Total Area (acres) 13,843

	Year: 1970	2000
Population:	292,926	262,174
A. Sewer Service (population)		
1. Separate Sanitary	158,832	142,157
2. Combined	134,094	120,017
3. Unsewered	0	0
4. Total Sewered Population	292,926	262,174
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	4,540	3,825
b. Commercial	2,161	2,902
c. Industrial	1,474	1,248
d. Other	13	12
e. Total Storm Sewer Area	8,188	7,987
2. Combined Sewers		
a. Residential	1,594	1,342
b. Commercial	758	1,018
c. Industrial	517	438
d. Other	4	4
e. Total Combined Area	2,873	2,802
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation		
6. Construction		
7. Total Non-Point Area	2,782	3,054

MUNICIPAL DATA FORMAT

Town/City: Boston
(Drainage to Inner Harbor)
Total Area (acres) 7,397

Year:	1970	2000
Population:	62,949	56,918
A. Sewer Service (population)		
1. Separate Sanitary	0	0
2. Combined	62,949	56,918
3. Unsewered	0	0
4. Total Sewered Population	62,949	56,918
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Storm Sewer Area		
2. Combined Sewers		
a. Residential	494	413
b. Commercial	756	683
c. Industrial	958	947
d. Other	71	71
e. Total Combined Area	2,279	2,114
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	713	378
6. Construction		
7. Total Non-Point Area	713	378

MUNICIPAL DATA FORMAT

Town/City: Boston
(Drainage to basin, upstream of
B.U. Bridge)
Total Area (acres) 5,390

Year:	1970	2000
Population:	113,386	101,930
A. Sewer Service (population)		
1. Separate Sanitary	105,344	94,822
2. Combined	7,942	7,108
3. Unsewered	0	0
4. Total Sewered Population	113,386	101,930
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,526	2,429
b. Commercial	1,082	992
c. Industrial	472	418
d. Other	7	-
e. Total Storm Sewer Area	4,087	3,346
2. Combined Sewers		
a. Residential	133	143
b. Commercial	69	58
c. Industrial	37	25
d. Other	1	0
e. Total Combined Area	240	226
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	1,063	
6. Construction		
7. Total Non-Point Area	1,063	1,318

MUNICIPAL DATA FORMAT

Town/City: Boston
(Drainage to Neponset)
Total Area (acres) 4,220

Year:	1970	2000
Population:	95,123	85,330
A. Sewer Service (population)		
1. Separate Sanitary	95,123	85,330
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	95,123	85,330
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,588	2,411
b. Commercial	653	420
c. Industrial	378	520
d. Other		
e. Total Storm Sewer Area	3,619	3,351
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	0
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	601	469
6. Construction		
7. Total Non-Point Area	601	469

MUNICIPAL DATA FORMAT

Town/City: Burlington
Total Area (acres) 7,503

Year:	1970	2000
Population:	21,980	33,058
A. Sewer Service (population)		
1. Separate Sanitary	10,770	33,058
2. Combined	0	0
3. Unsewered	11,210	0
4. Total Sewered Population	10,770	33,058
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,981	4,062
b. Commercial	358	1,445
c. Industrial	1,003	1,375
d. Other	30	30
e. Total Storm Sewer Area	4,372	6,912
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	364	36
2. Forest	2,124	501
3. Wetlands	121	29
4. Mining/Disposal	61	14
5. Recreation	61	61
6. Construction		
7. Total Non-Point Area	2,731	691

MUNICIPAL DATA FORMAT

Town/City: Cambridge
(Tributary to Mystic River)
Total Area (acres) 870

	1970	2000
Year:	1970	2000
Population:	4,960	5,279
A. Sewer Service (population)		
1. Separate Sanitary	4,960	5,279
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	4,960	5,279
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	341	358
b. Commercial	164	144
c. Industrial	168	194
d. Other	1	1
e. Total Storm Sewer Area	674	697
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	4	3
2. Forest	18	15
3. Wetlands	120	102
4. Mining/Disposal	9	8
5. Recreation	45	45
6. Construction		
7. Total Non-Point Area	196	173

MUNICIPAL DATA FORMAT

Town/City: Cambridge
(Drainage to basin, downstream of B.U. Bridge)
Total Area (acres) 1,120

	1970	2000
Year:	1970	2000
Population:	23,462	24,969
A. Sewer Service (population)		
1. Separate Sanitary	12,927	13,757
2. Combined	10,535	11,212
3. Unsewered	0	
4. Total Sewered Population	23,462	24,969
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	179	201
b. Commercial	66	81
c. Industrial	91	109
d. Other	11	1
e. Total Storm Sewer Area	347	392
2. Combined Sewers		
a. Residential	230	260
b. Commercial	85	104
c. Industrial	122	141
d. Other	10	0
e. Total Combined Area	447	505
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation		
6. Construction		
7. Total Non-Point Area	326	223

MUNICIPAL DATA FORMAT

Town/City: Cambridge
(Drainage to basin, upstream of B.U. Bridge)
Total Area (acres) 2,580

	1970	2000
Year:	1970	2000
Population:	71,971	76,594
A. Sewer Service (population)		
1. Separate Sanitary	48,401	51,510
2. Combined	23,570	25,084
3. Unsewered	0	
4. Total Sewered Population	71,971	76,590
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	575	641
b. Commercial	214	426
c. Industrial	294	347
d. Other	1	1
e. Total Storm Sewer Area	1,084	1,246
2. Combined Sewers		
a. Residential	379	421
b. Commercial	139	169
c. Industrial	194	229
d. Other	1	1
e. Total Combined Area	713	820
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation		
6. Construction		
7. Total Non-Point Area	783	514

MUNICIPAL DATA FORMAT

Town/City: Canton
Total Area (acres) 12,403

	1970	2000
Year:	1970	2000
Population	17,100	34,635
A. Sewer Service (population)		
1. Separate Sanitary	8,892	32,903
2. Combined	0	0
3. Unsewered	8,208	1,732
4. Total Sewered Population	8,892	32,903
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,772	4,518
b. Commercial	471	862
c. Industrial	923	960
d. Other	0	0
e. Total Storm Sewer Area	4,166	6,340
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	1,002	718
2. Forest	5,566	3,991
3. Wetlands	390	638
4. Mining/Disposal	223	160
5. Recreation	556	556
6. Construction		
7. Total Non-Point Area	8,237	6,063

MUNICIPAL DATA FORMAT

Town/City: Charlestown (Boston)   Year: 1970   2000

Total Area (acres) 1,071   Population: 15,417   11,035

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	4,317	11,035
2. Combined	11,100	0
3. Unsewered	0	0
4. Total Sewered Population	15,417	11,035
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	17	54
b. Commercial	45	95
c. Industrial	150	591
d. Other	21	81
e. Total Storm Sewer Area	233	821
2. Combined Sewers		
a. Residential	50	
b. Commercial	135	
c. Industrial	445	
d. Other	60	
e. Total Combined Area	690	0
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	148	250
6. Construction		
7. Total Non-Point Area	148	250

MUNICIPAL DATA FORMAT

Town/City: Chelsea   Year: 1970   2000

Total Area (acres) 1,389   Population: 30,643   20,535

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	20,543	20,535
2. Combined	10,100	0
3. Unsewered	0	0
4. Total Sewered Population	30,643	20,535
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	328	166
b. Commercial	79	57
c. Industrial	280	188
d. Other	1	1
e. Total Storm Sewer Area	688	412
2. Combined Sewers		
a. Residential	220	
b. Commercial	52	
c. Industrial	188	
d. Other	0	
e. Total Combined Area	460	0
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	241	377
6. Construction		
7. Total Non-Point Area	241	377

MUNICIPAL DATA FORMAT

Town/City: Dedham   Year: 1970   2000

Total Area (acres) 6,906   Population: 27,645   29,192

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	23,774	29,192
2. Combined	0	0
3. Unsewered	3,871	0
4. Total Sewered Population	23,774	29,192
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,124	3,113
b. Commercial	1,079	1,228
c. Industrial	530	742
d. Other	0	0
e. Total Storm Sewer Area	3,733	5,088
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	118	56
2. Forest	2,325	1,294
3. Wetlands	588	327
4. Mining/Disposal	24	13
5. Recreation	118	118
6. Construction		
7. Total Non-Point Area	3,173	1,818

MUNICIPAL DATA FORMAT

Town/City: Dorchester   Year: 1970   2000
(Drainage to Dorchester)
(Dorchester Interceptor)
Total Area (acres) 3,710   Population: 82,649   89,519

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	31,760	34,383
2. Combined	50,920	55,136
3. Unsewered	0	0
4. Total Sewered Population	82,680	89,519
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	925	1,098
b. Commercial	127	398
c. Industrial	270	346
d. Other	-	3
e. Total Storm Sewer Area	1,325	1,845
2. Combined Sewers		
a. Residential	514	684
b. Commercial	267	238
c. Industrial	168	225
d. Other	2	2
e. Total Combined Area	951	1,149
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	1,231	716
6. Construction		
7. Total Non-Point Area		

MUNICIPAL DATA FORMAT

Town/City: Dover	Year: 1970	2000
Total Area (acres) 9,798 Population:	4,529	10,780
A. Sewer Service (population)		
1. Separate Sanitary	0	0
2. Combined		
3. Unsewered	4,529	10,780
4. Total Sewered Population	0	0
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,650	3,894
b. Commercial	110	155
c. Industrial	119	141
d. Other	0	0
e. Total Storm Sewer Area	1,879	4,190
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	1,188	840
2. Forest	6,387	4,513
3. Wetlands	297	210
4. Mining/Disposal	7	5
5. Recreation	40	40
6. Construction		
7. Total Non-Point Area	7,919	5,608

MUNICIPAL DATA FORMAT

Town/City: East Boston (Inner Harbor and Chelsea Cr.)	Year: 1970	2000
Total Area (acres) 3,689 Population:	38,830	29,012
A. Sewer Service (population)		
1. Separate Sanitary	30,230	22,586
2. Combined	8,600	6,426
3. Unsewered	0	0
4. Total Sewered Population	38,830	29,012
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	260	205
b. Commercial	158	81
c. Industrial	1,195	1,187
d. Other	47	47
e. Total Storm Sewer Area	1,661	1,520
2. Combined Sewers		
a. Residential	157	123
b. Commercial	95	48
c. Industrial	720	715
d. Other	29	29
e. Total Combined Area	1,000	915
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	1,028	1,254
6. Construction		
7. Total Non-Point Area	1,028	1,254

MUNICIPAL DATA FORMAT

Town/City: Everett	Year: 1970	2000
Total Area (acres) 2,400 Population:	42,478	35,551
A. Sewer Service (population)		
1. Separate Sanitary	42,478	35,551
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	42,478	35,551
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,026	868
b. Commercial	155	83
c. Industrial	569	531
d. Other	47	47
e. Total Storm Sewer Area	1,797	1,529
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	16	16
2. Forest	17	17
3. Wetlands	445	444
4. Mining/Disposal	11	11
5. Recreation	114	383
6. Construction		
7. Total Non-Point Area	603	871

MUNICIPAL DATA FORMAT

Town/City: Franklin	Year: 1970	2000
Total Area (acres) 17,280 Population:	18,067	28,495
A. Sewer Service (population)		
1. Separate Sanitary	8,310	22,796
2. Combined	0	0
3. Unsewered	9,757	5,699
4. Total Sewered Population	8,310	22,796
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,127	3,883
b. Commercial	298	497
c. Industrial	505	596
d. Other	0	0
e. Total Storm Sewer Area	2,930	4,976
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	2,594	2,220
2. Forest	10,720	9,173
3. Wetlands	690	590
4. Mining/Disposal	173	148
5. Recreation	173	173
6. Construction		
7. Total Non-Point Area	14,350	12,304

MUNICIPAL DATA FORMAT

Town/City: Holliston	Year:	1970	2000
Total Area (acres) 12,224	Population:	12,069	20,218
A. Sewer Service (population)			
1. Separate Sanitary		0	10,108
2. Combined		0	0
3. Unsewered		12,069	10,110
4. Total Sewered Population		0	10,108
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		1,914	3,548
b. Commercial		231	460
c. Industrial		390	457
d. Other		0	0
e. Total Storm Sewer Area		2,535	4,465
2. Combined Sewers			
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area			
C. Non-Point Source Areas (acres)			
1. Agriculture		428	344
2. Forest		8,836	7,105
3. Wetlands		214	172
4. Mining/Disposal		107	36
5. Recreation		54	54
6. Construction			
7. Total Non-Point Area		9,639	7,759

MUNICIPAL DATA FORMAT

Town/City: Hopkinton	Year:	1970	2000
Total Area (acres) 17,369	Population:	5,981	15,072
A. Sewer Service (population)			
1. Separate Sanitary		0	9,043
2. Combined		0	
3. Unsewered		5,981	6,029
4. Total Sewered Population		0	9,043
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		1,211	2,747
b. Commercial		115	577
c. Industrial		443	584
d. Other		5	5
e. Total Storm Sewer Area		1,774	3,913
2. Combined Sewers			
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area			
C. Non-Point Source Areas (acres)			
1. Agriculture		1,462	1,266
2. Forest		12,547	11,294
3. Wetlands		1,230	1,108
4. Mining/Disposal		164	142
5. Recreation		146	146
6. Construction			
7. Total Non-Point Area		16,095	13,956

MUNICIPAL DATA FORMAT

Town/City: Lexington	Year:	1970	2000
Total Area (acres) 10,643	Population:	31,893	43,528
A. Sewer Service (population)			
1. Separate Sanitary		24,557	39,174
2. Combined		0	0
3. Unsewered		7,336	4,354
4. Total Sewered Population		24,557	39,174
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		5,171	6,912
b. Commercial		734	939
c. Industrial		393	531
d. Other		0	0
e. Total Storm Sewer Area		6,298	8,382
2. Combined Sewers		0	
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area		0	
C. Non-Point Source Areas (acres)			
1. Agriculture		647	323
2. Forest		2,719	1,337
3. Wetlands		740	369
4. Mining/Disposal		55	27
5. Recreation		185	185
6. Construction			
7. Total Non-Point Area		4,345	2,261

MUNICIPAL DATA FORMAT

Town/City: Lincoln	Year:	1970	2000
Total Area (acres) 9,594	Population:	7,567	14,022
A. Sewer Service (population)			
1. Separate Sanitary		0	5,608
2. Combined		0	0
3. Unsewered		7,567	8,414
4. Total Sewered Population		0	5,608
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		1,913	3,587
b. Commercial		96	172
c. Industrial		306	331
d. Other		5	5
e. Total Storm Sewer Area		2,320	4,095
2. Combined Sewers		0	
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area		0	
C. Non-Point Source Areas (acres)			
1. Agriculture		1,376	1,039
2. Forest		5,063	3,823
3. Wetlands		786	593
4. Mining/Disposal		20	15
5. Recreation		29	29
6. Construction			
7. Total Non-Point Area		7,274	5,499

MUNICIPAL DATA FORMAT

Town/City: Malden Year:	1970	2000
Total Area (acres) 3,283 Population:	56,127	50,987
A. Sewer Service (population)		
1. Separate Sanitary	56,127	50,987
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	56,127	50,987
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,020	1,808
b. Commercial	320	197
c. Industrial	270	396
d. Other	0	0
e. Total Storm Sewer Area	2,610	2,401
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	64	64
2. Forest	420	418
3. Wetlands	29	29
4. Mining/Disposal	64	63
5. Recreation	96	308
6. Construction		
7. Total Non-Point Area	673	882

MUNICIPAL DATA FORMAT

Town/City: Medfield Year:	1970	2000
Total Area (acres) 9,293 Population:	9,821	19,610
A. Sewer Service (population)		
1. Separate Sanitary	1,473	15,687
2. Combined	0	0
3. Unsewered	8,348	3,923
4. Total Sewered Population	1,473	15,687
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,770	3,508
b. Commercial	215	411
c. Industrial	225	380
d. Other	0	0
e. Total Storm Sewer Area	2,210	4,299
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	1,049	737
2. Forest	5,221	3,670
3. Wetlands	700	492
4. Mining/Disposal	61	43
5. Recreation	52	52
6. Construction		
7. Total Non-Point Area	7,083	4,994

MUNICIPAL DATA FORMAT

Town/City: Medford Year:	1970	2000
Total Area (acres) 5,606 Population:	64,409	67,330
A. Sewer Service (population)		
1. Separate Sanitary	63,764	67,330
2. Combined	0	0
3. Unsewered	645	0
4. Total Sewered Population	63,764	67,330
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,623	2,695
b. Commercial	384	244
c. Industrial	371	465
d. Other	2	2
e. Total Storm Sewer Area	3,380	3,406
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	111	110
2. Forest	1,419	1,401
3. Wetlands	445	438
4. Mining/Disposal	28	28
5. Recreation	223	223
6. Construction		
7. Total Non-Point Area	2,226	2,200

MUNICIPAL DATA FORMAT

Town/City: Medway Year:	1970	2000
Total Area (acres) 7,462 Population:	7,829	12,762
A. Sewer Service (population)		
1. Separate Sanitary	313	7,657
2. Combined	0	0
3. Unsewered	7,516	5,105
4. Total Sewered Population	313	7,657
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,316	1,997
b. Commercial	112	334
c. Industrial	341	434
d. Other	0	0
e. Total Storm Sewer Area	1,769	2,765
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	1,617	1,332
2. Forest	3,751	3,090
3. Wetlands	141	116
4. Mining/Disposal	141	116
5. Recreation	43	43
6. Construction		
7. Total Non-Point Area	5,693	4,697

MUNICIPAL DATA FORMAT

Town/City: Melrose	Year: 1970	2000
Total Area (acres) 3,072	Population: 33,198	38,120
A. Sewer Service (population)		
1. Separate Sanitary	33,198	38,120
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	33,198	38,120
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,938	2,159
b. Commercial	192	125
c. Industrial	90	110
d. Other	3	3
e. Total Storm Sewer Area	2,224	2,397
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	12	9
2. Forest	636	484
3. Wetlands	50	38
4. Mining/Disposal	25	19
5. Recreation	125	125
6. Construction		
7. Total Non-Point Area	848	675

MUNICIPAL DATA FORMAT

Town/City: Milford	Year: 1970	2000
Total Area (acres) 9,594	Population: 19,352	23,172
A. Sewer Service (population)		
1. Separate Sanitary	17,610	22,012
2. Combined	0	
3. Unsewered	1,742	1,160
4. Total Sewered Population	17,610	22,012
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,969	2,399
b. Commercial	315	394
c. Industrial	395	450
d. Other	0	0
e. Total Storm Sewer Area	2,679	3,243
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	629	577
2. Forest	5,601	5,140
3. Wetlands	551	506
4. Mining/Disposal	73	67
5. Recreation	61	61
6. Construction		
7. Total Non-Point Area	6,915	6,351

MUNICIPAL DATA FORMAT

Town/City: Millis	Year: 1970	2000
Total Area (acres) 7,846	Population: 5,795	13,965
A. Sewer Service (population)		
1. Separate Sanitary	1,448	11,172
2. Combined	0	0
3. Unsewered	4,347	2,793
4. Total Sewered Population	1,448	11,172
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	907	2,042
b. Commercial	76	266
c. Industrial	226	266
d. Other	16	16
e. Total Storm Sewer Area	1,225	2,590
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	1,522	1,201
2. Forest	4,186	3,303
3. Wetlands	609	480
4. Mining/Disposal	152	120
5. Recreation	152	152
6. Construction		
7. Total Non-Point Area	6,621	5,256

MUNICIPAL DATA FORMAT

Town/City: Milton	Year: 1970	2000
Total Area (acres) 5,148	Population: 27,190	36,331
A. Sewer Service (population)		
1. Separate Sanitary	20,691	31,235
2. Combined	0	0
3. Unsewered	6,499	5,096
4. Total Sewered Population	20,691	31,235
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,294	2,529
b. Commercial	306	429
c. Industrial	166	211
d. Other	46	0
e. Total Storm Sewer Area	1,812	3,169
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	305	254
2. Forest	2,730	1,318
3. Wetlands	244	204
4. Mining/Disposal	21	20
5. Recreation	183	183
6. Construction		
7. Total Non-Point Area	3,336	1,979

MUNICIPAL DATA FORMAT

Town/City: Natick Year: 1970 2000

Total Area (acres) 10,234 Population: 31,047 41,629

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	21,422	37,465
2. Combined	0	0
3. Unsewered	9,625	4,164
4. Total Sewered Population	21,422	37,465
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	3,673	4,766
b. Commercial	700	995
c. Industrial	612	909
d. Other	86	86
e. Total Storm Sewer Area	5,071	6,756
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	774	513
2. Forest	3,486	2,309
3. Wetlands	688	456
4. Mining/Disposal	43	28
5. Recreation	172	172
6. Construction		
7. Total Non-Point Area	5,163	3,478

MUNICIPAL DATA FORMAT

Town/City: Needham Year: 1970 2000

Total Area (acres) 8,160 Population 29,709 44,124

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	25,549	44,124
2. Combined	0	0
3. Unsewered	4,160	0
4. Total Sewered Population	25,549	44,124
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	3,768	4,866
b. Commercial	542	567
c. Industrial	457	487
d. Other	278	278
e. Total Storm Sewer Area	5,045	6,198
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	254	156
2. Forest	2,200	1,351
3. Wetlands	509	313
4. Mining/Disposal	25	15
5. Recreation	127	127
6. Construction		
7. Total Non-Point Area	3,115	1,962

MUNICIPAL DATA FORMAT

Town/City: Newton Year: 1970 2000

Total Area (acres) 11,731 Population: 91,073 105,835

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	91,073	105,835
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	91,073	105,835
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	6,790	7,926
b. Commercial	1,511	1,324
c. Industrial	378	496
d. Other	1	0
e. Total Storm Sewer Area	8,680	9,743
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	122	63
2. Forest	1,672	863
3. Wetlands	366	189
4. Mining/Disposal	37	19
5. Recreation	854	854
6. Construction		
7. Total Non-Point Area	3,051	1,988

MUNICIPAL DATA FORMAT

Town/City: Norfolk Year: 1970 2000

Total Area (acres) 9,824 Population: 4,656 10,973

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	0	0
2. Combined	0	0
3. Unsewered	4,656	10,973
4. Total Sewered Population	0	0
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,922	3,566
b. Commercial	918	961
c. Industrial	732	743
d. Other	0	0
e. Total Storm Sewer Area	3,572	5,270
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	1,054	767
2. Forest	4,756	3,460
3. Wetlands	351	255
4. Mining/Disposal	70	51
5. Recreation	21	21
6. Construction		
7. Total Non-Point Area	6,252	4,554

MUNICIPAL DATA FORMAT

Town/City: Norwood

Total Area (acres) 6,778

	1970	2000
Year:	1970	2000
Population:	30,658	38,051
A. Sewer Service (population)		
1. Separate Sanitary	30,349	38,051
2. Combined	0	0
3. Unsewered	309	0
4. Total Sewered Population	30,349	38,051
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,513	3,128
b. Commercial	479	428
c. Industrial	1,020	1,050
d. Other	12	12
e. Total Storm Sewer Area	4,024	4,618
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	410	316
2. Forest	1,846	1,421
3. Wetlands	293	225
4. Mining/Disposal	29	22
5. Recreation	176	176
6. Construction		
7. Total Non-Point Area	2,754	2,160

MUNICIPAL DATA FORMAT

Town/City: Quincy

Total Area (acres) 10,650

	1970	2000
Year:	1970	2000
Population:	87,966	102,925
A. Sewer Service (population)		
1. Separate Sanitary	87,966	102,925
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	87,966	102,925
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	4,263	4,596
b. Commercial	790	595
c. Industrial	1,418	1,372
d. Other	449	449
e. Total Storm Sewer Area	6,920	7,012
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	328	222
2. Forest	2,589	2,522
3. Wetlands	509	593
4. Mining/Disposal	152	149
5. Recreation	152	152
6. Construction		
7. Total Non-Point Area	3,730	3,638

MUNICIPAL DATA FORMAT

Town/City: Randolph

Total Area (acres) 6,605

	1970	2000
Year:	1970	2000
Population:	27,035	32,425
A. Sewer Service (population)		
1. Separate Sanitary	15,517	30,803
2. Combined	0	0
3. Unsewered	11,518	1,622
4. Total Sewered Population	15,517	30,803
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,948	3,604
b. Commercial	327	480
c. Industrial	295	410
d. Other	11	11
e. Total Storm Sewer Area	3,581	4,505
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	296	204
2. Forest	2,235	1,542
3. Wetlands	415	287
4. Mining/Disposal	36	25
5. Recreation	42	42
6. Construction		
7. Total Non-Point Area	3,024	2,100

MUNICIPAL DATA FORMAT

Town/City: Reading

Total Area (acres) 6,304

	1970	2000
Year:	1970	2000
Population:	22,339	32,232
A. Sewer Service (population)		
1. Separate Sanitary	13,323	29,008
2. Combined	0	0
3. Unsewered	9,016	3,224
4. Total Sewered Population	13,323	29,008
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,645	3,721
b. Commercial	404	554
c. Industrial	368	474
d. Other	74	74
e. Total Storm Sewer Area	3,491	4,823
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	151	75
2. Forest	2,391	1,195
3. Wetlands	100	50
4. Mining/Disposal	20	10
5. Recreation	151	151
6. Construction		
7. Total Non-Point Area	2,813	1,481

MUNICIPAL DATA FORMAT

Town/City: Sharon Year:	1970	2000
Total Area (acres) 15,558 Population:	12,367	21,496
A. Sewer Service (population)		
1. Separate Sanitary	0	10,747
2. Combined	0	0
3. Unsewered	12,367	10,749
4. Total Sewered Population	0	21,496
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,014	3,678
b. Commercial	518	697
c. Industrial	3,320	3,034
d. Other	5,852	7,409
e. Total Storm Sewer Area		
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	947	795
2. Forest	8,045	6,751
3. Wetlands	592	497
4. Mining/Disposal	98	82
5. Recreation	24	24
6. Construction		
7. Total Non-Point Area	9,706	8,149

MUNICIPAL DATA FORMAT

Town/City: Sherborn Year:	1970	2000
Total Area (acres) 9,850 Population:	3,316	9,997
A. Sewer Service (population)		
1. Separate Sanitary	0	0
2. Combined	0	0
3. Unsewered	3,316	9,997
4. Total Sewered Population	0	0
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,221	3,477
b. Commercial	148	223
c. Industrial	435	467
d. Other	0	0
e. Total Storm Sewer Area	1,804	4,167
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	1,520	1,073
2. Forest	6,034	4,260
3. Wetlands	447	316
4. Mining/Disposal	36	25
5. Recreation	9	9
6. Construction		
7. Total Non-Point Area	8,046	5,683

MUNICIPAL DATA FORMAT

Town/City: Somerville Year:	1970	2000
Total Area (acres) 2,637 Population:	88,732	69,064
A. Sewer Service (population)		
1. Separate Sanitary	37,632	29,291
2. Combined	51,100	39,773
3. Unsewered	0	0
4. Total Sewered Population	88,732	69,064
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	473	439
b. Commercial	180	99
c. Industrial	257	310
d. Other	0	0
e. Total Storm Sewer Area	910	848
2. Combined Sewers		
a. Residential	642	595
b. Commercial	245	135
c. Industrial	348	422
d. Other	0	0
e. Total Combined Area	1,235	1,152
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal	22	22
5. Recreation	470	615
6. Construction		
7. Total Non-Point Area	492	637

MUNICIPAL DATA FORMAT

Town/City: South Boston Year: (Drainage to Dorchester Bay) (South Boston Interceptor, South Branch)	1970	2000
Total Area (acres) 694 Population:	17,571	12,423
A. Sewer Service (population)		
1. Separate Sanitary	0	0
2. Combined	17,571	12,428
3. Unsewered	0	0
4. Total Sewered Population	17,571	12,428
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Storm Sewer Area	0	
2. Combined Sewers		
a. Residential	72	87
b. Commercial	30	39
c. Industrial	161	283
d. Other	14	25
e. Total Combined Area	277	434
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	417	260
6. Construction		
7. Total Non-Point Area	417	260

MUNICIPAL DATA FORMAT

Town/City: Stoneham	Year: 1970	2000
Total Area (acres) 4,252 — Population:	20,711	21,347
A. Sewer Service (population)		
1. Separate Sanitary	19,675	21,347
2. Combined	0	0
3. Unsewered	1,036	0
4. Total Sewered Population	19,975	21,347
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,888	1,942
b. Commercial	393	387
c. Industrial	151	194
d. Other	0	0
e. Total Storm Sewer Area	2,432	2,523
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	126	119
2. Forest	1,227	1,160
3. Wetlands	316	299
4. Mining/Disposal	3	3
5. Recreation	158	158
6. Construction		
7. Total Non-Point Area	1,830	1,739

MUNICIPAL DATA FORMAT

Town/City: Stoughton	Year: 1970	2000
Total Area (acres) 10,220 — Population	23,5[illegible]	36,171
A. Sewer Service (population)		
1. Separate Sanitary	5,143	32,423
2. Combined	0	0
3. Unsewered	7,871	3,118
4. Total Sewered Population	5,143	32,423
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,393	3,731
b. Commercial	310	380
c. Industrial	713	494
d. Other	4	4
e. Total Storm Sewer Area	4,354	5,305
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	585	470
2. Forest	5,265	4,225
3. Wetlands	293	234
4. Mining/Disposal	195	157
5. Recreation	34	38
6. Construction		
7. Total Non-Point Area	6,156	5,145

MUNICIPAL DATA FORMAT

Town/City: Wakefield	Year: 1970	2000
Total Area (acres) 5,050 — Population:	25,402	35,315
A. Sewer Service (population)		
1. Separate Sanitary	22,353	35,315
2. Combined	0	0
3. Unsewered	3,049	
4. Total Sewered Population	22,353	35,315
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,182	2,976
b. Commercial	315	275
c. Industrial	200	265
d. Other		
e. Total Storm Sewer Area	2,697	3,516
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	0
C. Non-Point Source Areas (acres)		
1. Agriculture	160	102
2. Forest	1,535	975
3. Wetlands	555	340
4. Mining/Disposal	16	10
5. Recreation	107	107
6. Construction		
7. Total Non-Point Area	2,353	1,534

MUNICIPAL DATA FORMAT

Town/City: Walpole	Year: 1970	2000
Total Area (acres) 13,198 — Population	18,149	25,379
A. Sewer Service (population)		
1. Separate Sanitary	5,807	20,071
2. Combined	0	0
3. Unsewered	12,342	5,308
4. Total Sewered Population	5,807	20,071
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,396	5,231
b. Commercial	362	371
c. Industrial	736	778
d. Other	0	0
e. Total Storm Sewer Area	3,494	6,380
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	1,548	1,045
2. Forest	7,224	4,875
3. Wetlands	516	518
4. Mining/Disposal	587	261
5. Recreation	129	129
6. Construction		
7. Total Non-Point Area	9,904	6,828

MUNICIPAL DATA FORMAT

Town/City: Waltham

Total Area (acres) 8,953

	Year: 1970	2000
Population	61,582	65,014
A. Sewer Service (population)		
1. Separate Sanitary	46,186	65,014
2. Combined	0	0
3. Unsewered	15,396	0
4. Total Sewered Population	46,186	65,014
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	3,760	4,283
b. Commercial	1,701	1,688
c. Industrial	695	325
d. Other	4	4
e. Total Storm Sewer Area	6,160	6,300
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	332	243
2. Forest	1,479	1,082
3. Wetlands	554	405
4. Mining/Disposal	17	12
5. Recreation	111	111
6. Construction		
7. Total Non-Point Area	2,493	1,853

MUNICIPAL DATA FORMAT

Town/City: Watertown

Total Area (acres) 2,669

	Year: 1970	2000
Population	39,295	31,693
A. Sewer Service (population)		
1. Separate Sanitary	39,295	31,693
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	39,295	31,693
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,511	1,244
b. Commercial	404	265
c. Industrial	208	343
d. Other	92	92
e. Total Storm Sewer Area	2,215	1,944
2. Combined Sewers		
a. Residential	0	
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	65	103
2. Forest	91	144
3. Wetlands	97	154
4. Mining/Disposal	6	10
5. Recreation	195	310
6. Construction		
7. Total Non-Point Area	454	721

MUNICIPAL DATA FORMAT

Town/City: Wellesley

Total Area (acres) 6,726

	Year: 1970	2000
Population	28,047	31,646
A. Sewer Service (population)		
1. Separate Sanitary	22,718	31,646
2. Combined	0	0
3. Unsewered	5,329	0
4. Total Sewered Population	22,718	31,646
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	3,927	4,130
b. Commercial	1,354	1,410
c. Industrial	155	178
d. Other	0	0
e. Total Storm Sewer Area	5,436	5,718
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	38	29
2. Forest	868	652
3. Wetlands	228	172
4. Mining/Disposal	4	3
5. Recreation	152	152
6. Construction		
7. Total Non-Point Area	1,290	1,008

MUNICIPAL DATA FORMAT

Town/City: Weston

Total Area (acres) 11,110

	Year: 1970	2000
Population	10,878	22,003
A. Sewer Service (population)		
1. Separate Sanitary	0	17,202
2. Combined	0	0
3. Unsewered	10,878	4,801
4. Total Sewered Population	0	17,202
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	4,058	6,826
b. Commercial	585	815
c. Industrial	265	416
d. Other	0	0
e. Total Storm Sewer Area	4,908	8,057
2. Combined Sewers	0	
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	
C. Non-Point Source Areas (acres)		
1. Agriculture	564	264
2. Forest	4,914	2,300
3. Wetlands	376	176
4. Mining/Disposal	66	31
5. Recreation	282	282
6. Construction		
7. Total Non-Point Area	6,202	3,053

MUNICIPAL DATA FORMAT

Town/City: Westwood Year: 1970 2000

Total Area (acres) 7,194 Population: 12,748 22,810

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	4,335	22,341
2. Combined	0	0
3. Unsewered	8,413	469
4. Total Sewered Population	4,335	22,341
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,590	4,342
b. Commercial	400	706
c. Industrial	415	519
d. Other	0	0
e. Total Storm Sewer Area	3,405	5,567
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	335	129
2. Forest	2,921	1,129
3. Wetlands	224	36
4. Mining/Disposal	39	15
5. Recreation	168	168
6. Construction		
7. Total Non-Point Area	3,689	1,527

MUNICIPAL DATA FORMAT

Town/City: Wilmington Year: 1970 2000

Total Area (acres) 10,357 Population: 17,103 31,959

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	171	27,165
2. Combined	0	0
3. Unsewered	16,932	4,794
4. Total Sewered Population	171	27,165
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	3,710	4,140
b. Commercial	401	915
c. Industrial	999	1,240
d. Other	0	0
e. Total Storm Sewer Area	5,110	6,295
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	563	448
2. Forest	5,301	3,381
3. Wetlands	442	299
4. Mining/Disposal	331	224
5. Recreation	110	110
6. Construction		
7. Total Non-Point Area	6,847	4,462

MUNICIPAL DATA FORMAT

Town/City: Winchester Year: 1970 2000

Total Area (acres) 3,919 Population: 22,211 25,149

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	22,211	25,149
2. Combined	0	0
3. Unsewered	0	0
4. Total Sewered Population	22,211	25,149
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,462	2,767
b. Commercial	136	54
c. Industrial	72	89
d. Other		
e. Total Storm Sewer Area	2,670	2,910
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	96	73
2. Forest	996	305
3. Wetlands	161	130
4. Mining/Disposal		
5. Recreation	96	96
6. Construction		
7. Total Non-Point Area	1,349	1,109

MUNICIPAL DATA FORMAT

Town/City: Winthrop Year: 1970 2000

Total Area (acres) 1,343 Population: 20,335 14,605

	1970	2000
A. Sewer Service (population)		
1. Separate Sanitary	20,335	14,605
2. Combined	0	0
3. Unsewered	0	
4. Total Sewered Population	20,335	14,605
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	457	315
b. Commercial	147	79
c. Industrial	98	104
d. Other	61	61
e. Total Storm Sewer Area	763	559
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area	0	0
C. Non-Point Source Areas (acres)		
1. Agriculture	25	55
2. Forest	0	0
3. Wetlands	75	198
4. Mining/Disposal	26	58
5. Recreation	153	153
6. Construction		
7. Total Non-Point Area	280	484

MUNICIPAL DATA FORMAT

Town/City: Woburn	Year:	1970	2000
Total Area (acres) 8,390	Population:	37,406	50,346
A. Sewer Service (population)			
1. Separate Sanitary		27,680	50,346
2. Combined		0	0
3. Unsewered		9,726	0
4. Total Sewered Population		27,680	50,346
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		3,335	4,110
b. Commercial		345	614
c. Industrial		1,213	1,242
d. Other		0	0
e. Total Storm Sewer Area		4,893	5,966
2. Combined Sewers			
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area			
C. Non-Point Source Areas (acres)			
1. Agriculture		714	490
2. Forest		2,141	1,470
3. Wetlands		428	295
4. Mining/Disposal		143	98
5. Recreation		71	71
6. Construction			
7. Total Non-Point Area		3,497	2,424

MUNICIPAL DATA FORMAT

Town/City: Wrentham	Year:	1970	2000
Total Area (acres) 14,515	Population:	7,494	14,456
A. Sewer Service (population)			
1. Separate Sanitary		0	7,227
2. Combined		0	0
3. Unsewered		7,494	7,229
4. Total Sewered Population		0	7,227
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		1,102	2,328
b. Commercial		377	549
c. Industrial		511	617
d. Other		0	0
e. Total Storm Sewer Area		1,990	3,494
2. Combined Sewers		0	
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area		0	
C. Non-Point Source Areas (acres)			
1. Agriculture		2,366	2,081
2. Forest		9,128	8,028
3. Wetlands		696	612
4. Mining/Disposal		278	244
5. Recreation		56	56
6. Construction			
7. Total Non-Point Area		12,524	11,021

APPENDIX C

POPULATIONS, SEWERAGE SERVICES AND LAND USE DISTRIBUTIONS BY WATER QUALITY SECTIONS

Charles River
Section 1

Source to Milford Sewage Treatment Plant (mile 73.4)

Year:	1970	2000
Total Area (acres) 10,109 Population:	17,265	21,495
A. Sewer Service (population)		
1. Separate Sanitary	15,145	19,871
2. Combined	0	0
3. Unsewered	2,120	1,625
4. Total Sewered Population	15,145	19,871
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	1,819	2,349
b. Commercial	283	399
c. Industrial	386	448
d. Other	0	0
e. Total Storm Sewer Area	2,488	3,196
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	693	623
2. Forest	6,132	5,395
3. Wetlands	607	550
4. Mining/Disposal	80	72
5. Recreation	68	68
6. Construction		
7. Total Non-Point Area	7,621	6,913

Charles River
Section 2

Mine Brook to Stop River (mile 31.8)

Year:	1970	2000
Total Area (acres) 34,318 Population:	29,781	50,338
A. Sewer Service (population)		
1. Separate Sanitary	7,350	31,455
2. Combined	0	0
3. Unsewered	21,931	18,883
4. Total Sewered Population	7,350	31,455
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	4,683	8,308
b. Commercial	1,004	1,502
c. Industrial	1,386	1,613
d. Other	0	0
e. Total Storm Sewer Area	7,073	11,423
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	5,319	4,628
2. Forest	19,795	16,608
3. Wetlands	1,243	1,043
4. Mining/Disposal	453	381
5. Recreation	235	235
6. Construction		
7. Total Non-Point Area	27,245	22,895

Charles River
Section 3

Milford Sewage Treatment Plant to Mine Brook (mile 63.1)

Year:	1970	2000
Total Area (acres) 5,069 Population	5,866	7,258
A. Sewer Service (population)		
1. Separate Sanitary	0	5,806
2. Combined	0	0
3. Unsewered	5,866	1,452
4. Total Sewered Population	0	5,806
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	737	974
b. Commercial	155	213
c. Industrial	255	285
d. Other	0	0
e. Total Storm Sewer Area	1,147	1,472
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	726	665
2. Forest	2,712	2,485
3. Wetlands	291	266
4. Mining/Disposal	145	133
5. Recreation	48	48
6. Construction		
7. Total Non-Point Area	3,922	2,397

Charles River
Section 4

Stop River to South Natick Dam (mile 41.1)

Year:	1970	2000
Total Area (acres) 51,684 Population	51,595	94,575
A. Sewer Service (population)		
1. Separate Sanitary	15,033	57,335
2. Combined	0	0
3. Unsewered	36,562	37,240
4. Total Sewered Population	15,033	57,335
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	9,167	17,849
b. Commercial	1,598	2,415
c. Industrial	1,983	2,422
d. Other	64	64
e. Total Storm Sewer Area	12,812	22,750
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	5,657	4,148
2. Forest	29,908	22,260
3. Wetlands	2,480	1,806
4. Mining/Disposal	437	330
5. Recreation	390	390
6. Construction		
7. Total Non-Point Area	38,872	28,934

Charles River
Section 5

South Natick Dam to Mother Brook (mile 26.5)

Year:	1970	2000
Total Area (acres) 16,381 Population	43,782	40,113
A. Sewer Service (population)		
1. Separate Sanitary	33,452	33,318
2. Combined	0	0
3. Unsewered	10,330	4,795
4. Total Sewered Population	33,452	33,318
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	6,173	8,679
b. Commercial	1,487	1,700
c. Industrial	673	848
d. Other	139	139
e. Total Storm Sewer Area	8,472	11,365
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	810	519
2. Forest	6,041	3,753
3. Wetlands	766	470
4. Mining/Disposal	19	21
5. Recreation	253	253
6. Construction		
7. Total Non-Point Area	7,309	5,016

Charles River
Section 6

Mother Brook to the Watertown Dam (mile 9.4)

Year:	1970	2000
Total Area (acres) 36,085 Population	209,078	266,179
A. Sewer Service (population)		
1. Separate Sanitary	169,364	255,624
2. Combined	0	0
3. Unsewered	39,714	10,555
4. Total Sewered Population	169,364	255,624
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	20,370	25,445
b. Commercial	3,341	3,264
c. Industrial	2,058	2,633
d. Other	178	177
e. Total Storm Sewer Area	25,947	31,519
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	2,172	1,428
2. Forest	13,228	8,024
3. Wetlands	2,448	1,587
4. Mining/Disposal	153	49
5. Recreation	1,205	1,338
6. Construction		
7. Total Non-Point Area	19,234	12,466

Charles River
Section 7

Watertown Dam to Cottage Farm (B.U.) Bridge (mile 3.7)

Year:	1970	2000
Total Area (acres) 7,370 Population	185,357	178,524
A. Sewer Service (population)		
1. Separate Sanitary	154,345	146,332
2. Combined	31,312	32,192
3. Unsewered	0	0
4. Total Sewered Population	185,357	178,524
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	3,101	3,070
b. Commercial	1,296	1,249
c. Industrial	766	765
d. Other	8	8
e. Total Storm Sewer Area	5,171	5,092
2. Combined Sewers		
a. Residential	492	564
b. Commercial	228	227
c. Industrial	231	254
d. Other	2	1
e. Total Combined Area	953	1,046
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	1,446	1,832
6. Construction		
7. Total Non-Point Area	1,446	1,832

Charles River
Section 8

Cottage Farm (B.U.) Bridge to the Science Museum Dam (mile 1.2)

Year:	1970	2000
Total Area (acres) 14,363 Population	316,388	287,143
A. Sewer Service (population)		
1. Separate Sanitary	171,759	155,914
2. Combined	144,629	131,229
3. Unsewered	0	0
4. Total Sewered Population	316,388	287,143
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	4,719	4,026
b. Commercial	2,227	2,083
c. Industrial	1,365	1,357
d. Other	21	13
e. Total Storm Sewer Area	8,335	7,479
2. Combined Sewers		
a. Residential	1,421	1,602
b. Commercial	443	1,122
c. Industrial	639	570
d. Other	14	1
e. Total Combined Area	2,520	3,307
C. Non-Point Source Areas (acres)		
1. Agriculture		
2. Forest		
3. Wetlands		
4. Mining/Disposal		
5. Recreation	3,108	3,108
6. Construction		
7. Total Non-Point Area	3,108	3,277

Mystic-Aberjona River System
Section 1

Source of the Aberjona River to its Confluence with Horn Pond Brook (mile 10.3)

Year:	1970	2000
Total Area (acres) 16,443 — Population:	71,784	91,662
A. Sewer Service (population)		
1. Separate Sanitary	56,385	90,794
2. Combined	0	0
3. Unsewered	15,399	868
4. Total Sewered Population	56,385	90,794
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	6,769	8,215
b. Commercial	1,045	1,430
c. Industrial	1,631	1,810
d. Other	23	23
e. Total Storm Sewer Area	9,468	11,478
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	954	651
2. Forest	4,657	3,226
3. Wetlands	901	581
4. Mining/Disposal	164	107
5. Recreation	299	299
6. Construction		
7. Total Non-Point Area	6,975	4,965

Mystic-Aberjona River System
Section 2

Horn Pond Brook to the Outlet of Upper Mystic Lake (mile 8.1)

Year:	1970	2000
Total Area (acres) 4,019 — Population:	22,211	25,149
A. Sewer Service (population)		
1. Separate Sanitary	22,211	25,149
2. Combined		
3. Unsewered		
4. Total Sewered Population	22,211	25,149
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	2,462	2,767
b. Commercial	136	54
c. Industrial	72	89
d. Other		
e. Total Storm Sewer Area	2,670	2,910
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	96	78
2. Forest	996	805
3. Wetlands	161	130
4. Mining/Disposal		
5. Recreation	96	96
6. Construction		
7. Total Non-Point Area	1,349	1,109

Mystic-Aberjona River System
Section 3

Outlet of Upper Mystic Lake to Outlet of Lower Mystic Lake (mile 7.4)

Year:	1970	2000
Total Area (acres) 9,342 — Population:	91,955	97,333
A. Sewer Service (population)		
1. Separate Sanitary	89,432	96,027
2. Combined		
3. Unsewered	2,523	1,306
4. Total Sewered Population	89,432	96,027
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	5,439	5,960
b. Commercial	568	501
c. Industrial	396	507
d. Other	1	1
e. Total Storm Sewer Area	6,404	6,969
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	270	172
2. Forest	1,707	1,290
3. Wetlands	648	534
4. Mining/Disposal	30	22
5. Recreation	283	354
6. Construction		
7. Total Non-Point Area	2,938	2,373

Mystic-Aberjona River System
Section 4

Mystic River from the Outlet of Lower Mystic Lake to the Amelia Earhart Dam (mile 2.0)

Year:	1970	2000
Total Area (acres) 11,801 — Population:	180,918	165,826
A. Sewer Service (population)		
1. Separate Sanitary	144,499	139,576
2. Combined	33,726	26,250
3. Unsewered	2,693	
4. Total Sewered Population	178,225	165,826
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	5,812	5,709
b. Commercial	1,060	728
c. Industrial	978	1,223
d. Other	33	33
e. Total Storm Sewer Area	7,883	7,693
2. Combined Sewers		
a. Residential	424	393
b. Commercial	162	89
c. Industrial	230	278
d. Other		
e. Total Combined Area	816	760
C. Non-Point Source Areas (acres)		
1. Agriculture	165	171
2. Forest	1,527	1,459
3. Wetlands	590	574
4. Mining/Disposal	95	91
5. Recreation	725	1,053
6. Construction		
7. Total Non-Point Area	3,102	3,348

Neponset River
Section 1

Neponset Reservoir to the Confluence with East Branch (mile 13.2)

Year:	1970	2000
Total Area (acres) 26,443 Population:	42,325	71,469
A. Sewer Service (population)		
1. Separate Sanitary	32,252	60,626
2. Combined		
3. Unsewered	10,573	10,843
4. Total Sewered Population	32,252	60,626
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	5,499	10,228
b. Commercial	1,105	1,536
c. Industrial	2,487	2,533
d. Other	6	8
e. Total Storm Sewer Area	9,097	14,305
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	2,466	1,698
2. Forest	13,155	9,147
3. Wetlands	1,041	742
4. Mining/Disposal	417	286
5. Recreation	267	267
6. Construction		
7. Total Non-Point Area	17,346	12,140

Neponset River
Section 2

East Branch to the Confluence with Mother Brook (mile 7.3)

Year:	1970	2000
Total Area (acres) [illegible] Population:	[illegible]	[illegible]
A. Sewer Service (population)		
1. Separate Sanitary	37,776	91,759
2. Combined		
3. Unsewered	26,722	7,360
4. Total Sewered Population	37,776	91,759
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	8,048	11,917
b. Commercial	1,350	2,312
c. Industrial	3,211	3,393
d. Other	11	11
e. Total Storm Sewer Area	12,620	17,633
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	2,000	1,450
2. Forest	13,370	9,370
3. Wetlands	1,636	1,171
4. Mining/Disposal	377	279
5. Recreation	764	764
6. Construction		
7. Total Non-Point Area	13,347	13,534

Neponset River
Section 3

Mother Brook to the Milton Lower Falls Dam (mile 4.2)

Year:	1970	2000
Total Area (acres) 11,485 Population:	116,306	114,575
A. Sewer Service (population)		
1. Separate Sanitary	110,917	110,192
2. Combined		
3. Unsewered	5,389	4,383
4. Total Sewered Population	110,917	110,192
B. Urban Runoff Areas (acres)		
1. Separate Storm Sewers		
a. Residential	6,251	6,564
b. Commercial	1,002	739
c. Industrial	521	701
d. Other	40	
e. Total Storm Sewer Area	7,344	8,054
2. Combined Sewers		
a. Residential		
b. Commercial		
c. Industrial		
d. Other		
e. Total Combined Area		
C. Non-Point Source Areas (acres)		
1. Agriculture	262	218
2. Forest	2,390	1,993
3. Wetlands	210	175
4. Mining/Disposal	21	17
5. Recreation	758	1,025
6. Construction		
7. Total Non-Point Area	3,641	3,431

Boston Harbor
Section 1

(Inner Harbor)

Total Area (acres) 9,981	Year:	1970	2000
	Population:	162,706	139,043
A. Sewer Service (population)			
1. Separate Sanitary		69,957	66,399
2. Combined		92,749	73,344
3. Unsewered			
4. Total Sewered Population		162,706	139,043
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		964	929
b. Commercial		336	262
c. Industrial		1,824	2,352
d. Other		85	145
e. Total Storm Sewer Area		3,210	3,688
2. Combined Sewers			
a. Residential		921	536
b. Commercial		1,038	731
c. Industrial		2,311	1,662
d. Other		160	100
e. Total Combined Area		4,430	3,029
C. Non-Point Source Areas (acres)			
1. Agriculture		5	5
2. Forest		6	6
3. Wetlands		156	155
4. Mining/Disposal		4	4
5. Recreation		2,170	3,094
6. Construction			
7. Total Non-Point Area		2,341	3,264

Boston Harbor
Section 2

(Dorchester Bay)

Total Area (acres) 6,424	Year:	1970	2000
	Population:	114,814	119,202
A. Sewer Service (population)			
1. Separate Sanitary		45,989	51,383
2. Combined		68,500	67,564
3. Unsewered		325	255
4. Total Sewered Population		114,489	118,947
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		1,679	2,014
b. Commercial		566	524
c. Industrial		491	562
d. Other		72	70
e. Total Storm Sewer Area		2,808	3,170
2. Combined Sewers			
a. Residential		586	771
b. Commercial		297	287
c. Industrial		329	498
d. Other		16	27
e. Total Combined Area		1,228	1,583
C. Non-Point Source Areas (acres)			
1. Agriculture		49	46
2. Forest		527	494
3. Wetlands		105	100
4. Mining/Disposal		24	33
5. Recreation		1,683	1,008
6. Construction			
7. Total Non-Point Area		2,388	1,671

Boston Harbor
Section 3

(Quincy Bay)

Total Area (acres) 3,195	Year:	1970	2000
	Population:	26,390	30,877
A. Sewer Service (population)			
1. Separate Sanitary		26,390	30,877
2. Combined			
3. Unsewered			
4. Total Sewered Population		26,390	30,877
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		1,279	1,349
b. Commercial		237	208
c. Industrial		425	412
d. Other		135	135
e. Total Storm Sewer Area		2,076	2,104
2. Combined Sewers			
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area			
C. Non-Point Source Areas (acres)			
1. Agriculture		68	67
2. Forest		777	757
3. Wetlands		183	178
4. Mining/Disposal		46	45
5. Recreation		46	46
6. Construction			
7. Total Non-Point Area		1,119	1,091

Boston Harbor
Section 4

(Outer Harbor)

Total Area (acres) 1,043	Year:	1970	2000
	Population:	20,335	14,605
A. Sewer Service (population)			
1. Separate Sanitary		20,335	14,605
2. Combined			
3. Unsewered			
4. Total Sewered Population		20,335	14,605
B. Urban Runoff Areas (acres)			
1. Separate Storm Sewers			
a. Residential		457	315
b. Commercial		147	79
c. Industrial		98	104
d. Other		61	61
e. Total Storm Sewer Area		763	559
2. Combined Sewers			
a. Residential			
b. Commercial			
c. Industrial			
d. Other			
e. Total Combined Area			
C. Non-Point Source Areas (acres)			
1. Agriculture		25	65
2. Forest			
3. Wetlands		76	198
4. Mining/Disposal		26	68
5. Recreation		153	153
6. Construction			
7. Total Non-Point Area		280	484

APPENDIX D

WATER QUALITY PROJECTION MODELS

APPENDIX D

WATER QUALITY PROJECTION MODELS

D.1 Upper Charles River Nutrient Model

If the average phosphorus loadings assumed in Table 5-2 are approximately correct, phosphorus fluxes from the source of the Charles River to the Watertown Dam can be represented by first order decay kinetics with a rate constant of 0.1 day^{-1}.

For point source loadings:

$$J_p = M_p e^{-kt} \tag{1}$$

where

J_p = phosphorus flux at t days downstream from M_p point source loading (lb/day);

k = first-order decay coefficient (day^{-1}).

For distributed, stormwater and nonpoint source, loadings along a given section:

$$J_{np} = M_{np} \frac{1-e^{-kt}}{kt} \tag{2}$$

where

J_{np} = phosphorus flux at t days downstream from M_{np} uniformly distributed loading along the t days (lb/day)

J_{np} at the end of one section then becomes a point source loading at the beginning of the next downstream section, so that at the end of any section:

$$J_i = M_{p_i} e^{-kt_i} + M_{np_i} \frac{1-e^{-kt_i}}{kt_i} + J_{i-1} e^{-kt_i} \tag{3}$$

Fluxes are converted to concentrations by:

$$C_i = 0.186 \frac{J_i}{Q_i} \qquad (4)$$

where

C_i = concentration at the end of section i, mg/l; and

Q_i = stream flow out of section i (cfs).

Travel times through each each water quality section and flow rates in the first and last model reach for each section were computed for the June 1973 sampling dates (representative flow at Charles River Village assumed at 124 cfs) using the DWPC model flow parameters listed in Table D-1. Phosphorus fluxes entering and leaving each section were then computed by Equations (2) and (3). These fluxes were divided by the flows in the first and last model reach for each section and dimensionally corrected to provide concentrations of total phosphorus in mg/l. These computed concentrations are compared with DWPC's observed June 1973 concentrations in Table D-2. These observed data are those from the nearest 1973 sampling station to the beginning or end of each water quality section.

The 1973 water quality data suggest that the 1973 wastewater discharge data may be low by about a factor of two. The model reflects the observation that the principal sources of the high phosphorus concentrations in the upper Charles (sections C1, C2 and C3) are the point sources. In section C4 and on downstream, the point source influence rapidly diminishes, to be replaced by a consistent background concentration between 0.2 and 0.3 mg/l originating from urban runoff and nonpoint sources. Figure D-1 is a display of available phosphorus data gathered over a seven year period from sampling near the end of section C6 (Watertown Dam), plotted against flow data from the USGS gauging station just upstream at Moody Street in Waltham. Phosphorus concentrations have been reasonably consistent over this period, averaging 0.21 mg/l with a maximum of 0.29 mg/l and a minimum of 0.10 mg/l, over a flow range of 24 to 290 cfs.

TABLE D-1

DWPC CHARLES RIVER MODEL PARAMETERS

Section	Reach	Upstream Mile	Low Flow (cfs)	r^{-1}	Q/Q_{CRV} (no diversion)	QCOEF (hrs)	QEXP	K_2	K_2/K_1	$\frac{K_2}{K_2-K_1}$
1	01	76.5	0.21		0.018	226	1.0	0.44	2.1	4.12
	02	75.5	0.49	0.90	0.042	109	0.89	1.9	9.05	11.90
2	03	73.4	0.72		0.062	120	0.89	1.0	4.76	7.21
	04	71.3	0.79		0.069	216	0.97	0.31	1.48	3.34
	05	70.3	0.89	0.75	0.077	477	0.80	0.42	2.0	4.0
	06	66.1	1.3	0.60	0.112	149	0.88	0.36	1.71	3.65
	07	64.6	1.6	0.50	0.135	5.6	0.56	3.2	15.24	18.45
	08	64.2	2.3		0.197	31.8	0.56	0.62	2.95	5.14
3	09	63.1	3.3		0.285	94.7	0.90	0.51	2.43	4.52
	10	62.9	3.8	0.85	0.324	93.0	0.56	0.68	3.24	5.47
	11	60.7	4.1	0.50	0.353	82.5	0.56	0.60	2.86	5.03
	12	59.0	4.2		0.365	258	0.90	0.91	4.33	6.73
	13	58.9	4.2		0.366	62.3	0.56	0.76	3.62	5.91
	14	57.6	5.3		0.461	1690	0.86	0.43	2.05	4.06
4	15	51.8	6.8		0.586	837	0.90	0.33	1.57	3.47
	16	49.9	7.0		0.603	631	0.90	0.34	1.62	3.53
	17	48.3	8.9		0.766	239	0.90	0.35	1.67	3.59
	18	47.8	8.9		0.768	2680	0.90	0.33	1.57	3.47
5	19	41.1	9.8	0.60	0.849	631	0.90	0.82	3.90	6.24
	20	39.4	10.9		0.944	3860	0.97	0.25	1.19	2.97
	21	34.6	11.6	0.60	1.000	117	0.71	1.1	5.24	7.74
	22	33.0	11.8		1.018	266	0.66	0.29	1.38	3.22
	23	29.8	12.1		1.048	394	0.66	0.22	1.05	2.78
6	24	26.5	8.3		1.077	677	0.66	0.30	1.43	3.28
	25	24.2	8.7		1.107	558	0.70	0.27	1.29	3.10
	26	21.2	9.1		1.143	235	0.77	0.24	1.14	2.91
	27	20.2	9.1	0.70	1.147	230	1.0	0.57	2.71	4.86
	28	20.0	9.1	0.60	1.148	96.2	0.59	0.60	2.86	5.03
	29	18.0	9.5		1.179	1590	0.95	0.32	1.52	3.41
	30	15.4	9.8		1.208	6980	1.0	0.19	0.90	2.59
	31	12.7	10.0	0.45	1.226	24	0.70	0.82	3.90	6.24
	32	12.2	10.8		1.288	41.8	0.70	0.40	1.90	3.88
	33	11.8	10.8	0.90	1.290	145	0.70	0.78	3.71	6.02
	34	9.8		0.80						

TABLE D-1 (Continued)

NOTES TO DWPC CHARLES RIVER MODEL PARAMETERS

Column	Explanation
1	ERT Water Quality Section
2	STREAM model reach
3	Upstream river mile
4	Computed 10-year, 7-day low flow without sewage treatment plant inflows and with one-third flow diverted through Mother Brook
5	Dam reaeration coefficients
6	Ratio of upstream drainage area to area at Charles River Village
7	Time of travel flow coefficient
8	Time of travel flow exponent: t, hours = QCOEF (flow)$^{-\text{QEXP}}$
9	Reaeration coefficient; K_1 = BOD decay coefficient
10	Stream purification factor (this is also the ratio of allowable BOD to critical oxygen deficit at the point of critical deficit)
11	Ratio of allowable BOD to critical oxygen deficit at the point of zero deficit.

TABLE D-2

COMPUTED VERSUS OBSERVED PHOSPHORUS CONCENTRATIONS

June, 1973: Q_{CRV} = 124 cfs

Section	Travel Time (days)	Flow Rates		Computed Phosphorus Concentrations (mg/l)							
				Point Sources		NPS and Stormwater		Totals		DWPC June 1973 Data	
		Q_o (cfs)	Q_t (cfs)	C_o	C_t	C_o	C_t	C_o	C_t	C_o	C_t
1	5.6	-	4.9	-	-	-	0.70	-	0.70	-	0.17
2	4.7	11.3	26.0	1.38	0.38	0.30	0.18	1.68	0.56	3.55	0.75
3	3.7	39.6	60.0	0.61	0.28	0.12	0.24	0.73	0.52	0.93	0.58
4	3.2	75.3	97.1	0.31	0.17	0.19	0.30	0.50	0.47	0.44	0.45
5	3.3	106.5	129.6	0.16	0.09	0.28	0.24	0.44	0.33	0.50	0.36
6	7.0	86.4	114.4	0.09	0.03	0.24	0.33	0.33	0.36	0.39	0.27

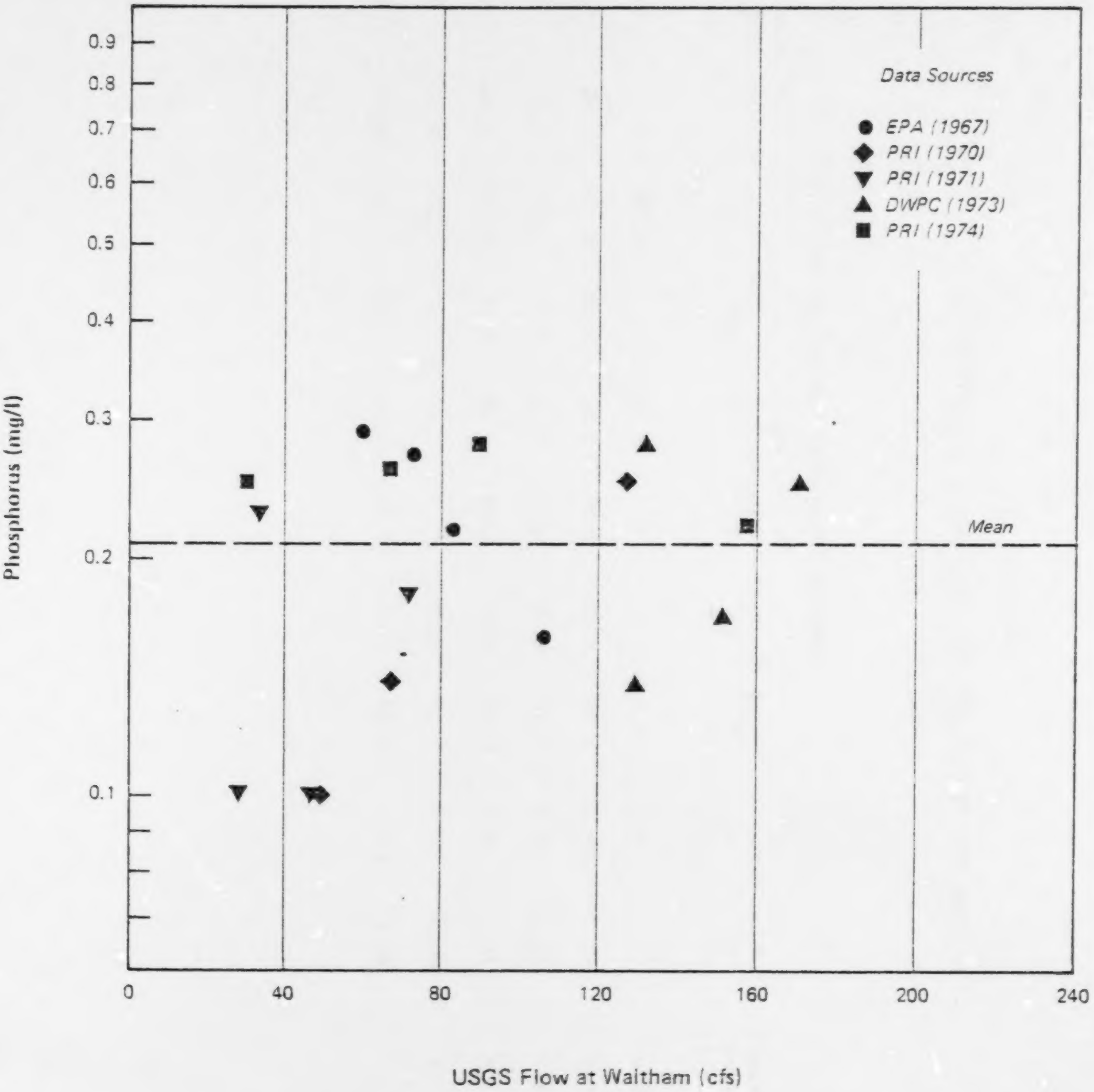


Figure D-1 Phosphorus Concentrations at Watertown Dam 1967-1974

Algal biomass is expressed in terms of chlorophyll-a. The maximum biomass which can be produced under nutrient limiting conditions is described by the Monad formulation developed and tested on the Potomac River estuary (Harris 1976):

$$[A]_{max} = \frac{1}{\frac{1}{N_T\ a_N} + \frac{1}{P_T\ a_p}} \tag{5}$$

where

$[A]_{max}$ = maximum nutrient limited algal mass, as chlorophyll-a (µg/l)

N_T = total nitrogen concentration (mg/l)

P_T = total phosphorus concentrations (mg/l)

a_N = ratio of chlorophyll-a to algal nitrogen concentrations (µg/mg)

a_P = ratio of chlorophyll-a to algal phosphorus concentrations (µg/mg)

The parameters a_N and a_P will vary with species and environmental conditions, but average about 100 and 1,000, respectively.

With a maximum allowable algal biomass represented by 25 µg/l chlorophyll-a, the allowable nutrient concentrations, for algal control purposes, can be expressed in terms of total phosphorus only. In urban stormwater runoff, the ratio of nitrogen to phosphorus is about 3 to 1. If, then, urban stormwater is the sole source of nutrients for a given water quality section, Equation (5) would indicate a control strategy to result in a maximum allowable phosphorus concentration of:

$$\frac{1}{300\ P_T} + \frac{1}{1{,}000\ P_T} \geq \frac{1}{25}$$

or

$$P_{MAX} \leq 0.11 \text{ mg/l},$$

if nitrogen and phosphorus are reduced at the same rates. The nitrogen to phosphorus ratio in combined sewer overflows is about 6 to 1. Where combined sewer overflows are the sole nutrient source, the maximum allowable phosphorus concentration would be 0.067 mg/l. The average nitrogen to phosphorus ratio for nonpoint sources is of the order of 20 to 1. Where nutrients are the sole result of nonpoint sources, an effective nutrient control strategy would need to result in a phosphorus concentration of less than 0.038 mg/l. For the purposes of this analysis, where nutrients in all cases result from a mixture of sources, a general control strategy objective was to limit total phosphorus concentrations to 0.05 mg/l.

D.2 Charles River Basin Model

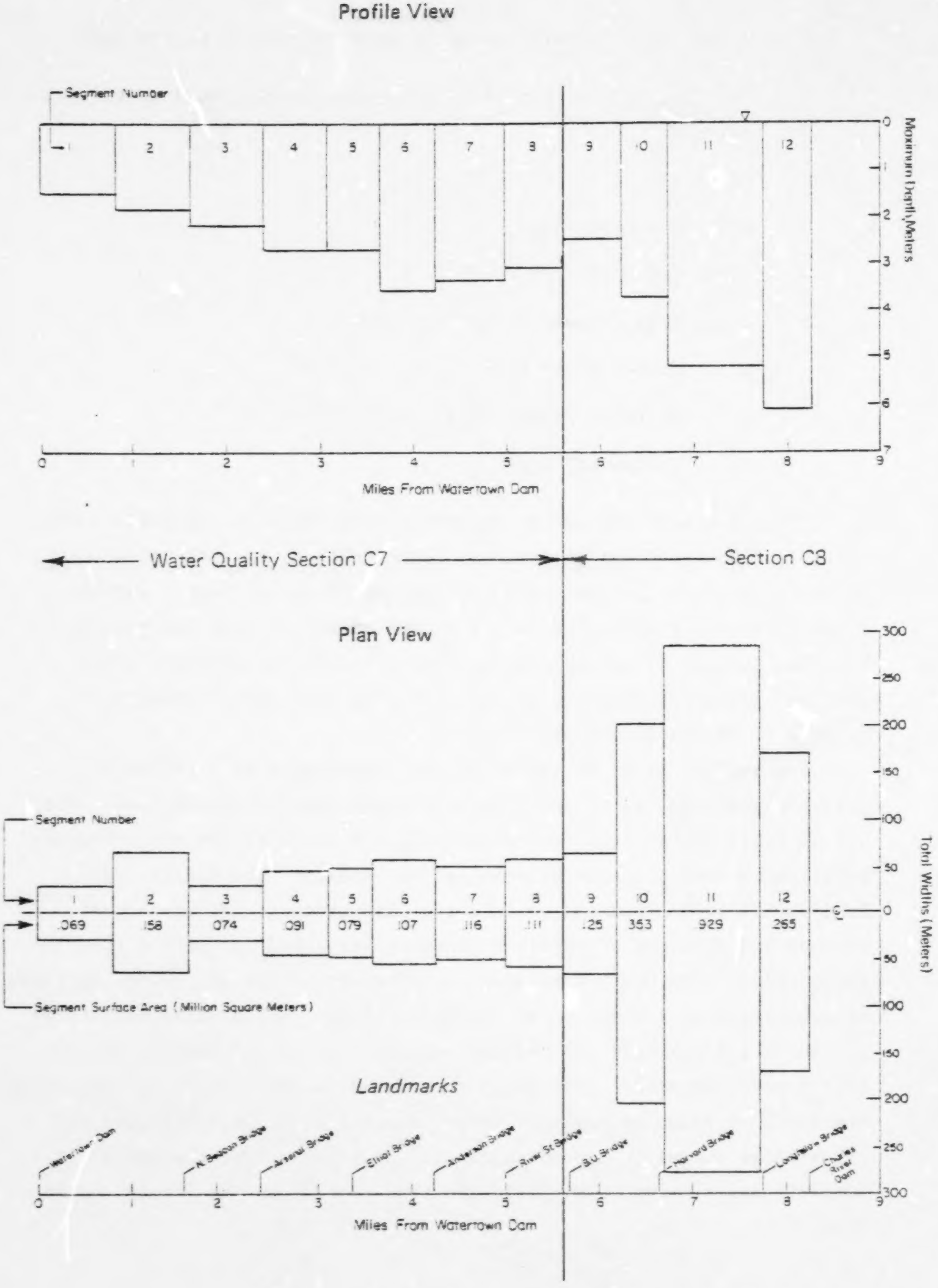
The original Charles River Basin model was designed to simulate water quality in the Basin as a function of river reach and season. The model simulated the dynamics of algal growth and decay in the Basin and computed secchi disc transparencies from concentrations of algal and non-algal turbidity elements. Respiration and settling were assumed to account for algal losses; predation was assumed to be unimportant, based on limited data on zooplankton populations in the Basin. The environmental factors which were assumed to control the algal and coliform populations in the river include chlorides, light, temperature and phosphorus. Based on results of water quality surveys performed during the summer of 1974, chlorides appeared to exert a controlling influence both on the algae and on the coliforms. Chloride gradients in the surface waters correlated with changes in coliform decay rates and major shifts in algal species with river reach and season. Another major environmental factor was light. Excessive levels of color and non-algal turbidity elements inhibit light penetration, thereby affecting algal growth and coliform decay rates. The effects of temperature on these rates was also included in the model. Under 1974 conditions, nutrients were not limiting algal populations. Phosphorus was, however, included as a possible future controlling factor for algal populations.

A total of seven primary variables were considered in the model:

1. Residual Optical Density (attributed to suspended solids and color)
2. Chlorides
3. Available Phosphorus
4. Total Coliforms
5. Three Algal Types:
    a. "fresh-water" type
    b. "brackish-water" type
    c. "saltwater" type

Predictions of the above components were based on the effects of: river flow and influent (Watertown) concentrations of each constituent; river temperature (calculated as a function of day of year); surface light intensity (calculated as a function of day of year and percent of possible sunshine); and pollution sources (estimated from the areas of combined and separate sewer systems draining into each segment and assumed to be steady-state).

The surface layer of the river was represented as a series of twelve mixed segments of approximately equal length (Figure D-2). The set of differential equations describing the above system was integrated numerically over a season between defined limits. The fourth order Runge-Kutta method was the technique of integration. River flow at Waltham and fraction of possible sunshine were read in daily during the integration. The model simulated the movement of the salt wedge upstream or downstream as a function of freshwater flow. While water quality in the surface layer only was modeled, concentrations and surface layer depths were included. This model considered the effects of destratifying the Basin by reducing the salt wedge penetration to zero. Figure D-3 illustrates the major control pathways which constitute the model. A complete description is given in the Final Report on the Storrow Lagoon Demonstration Plant.



Profile View

Plan View

Landmarks

Figure D-2 Original Charles River Basin Model Segmentation

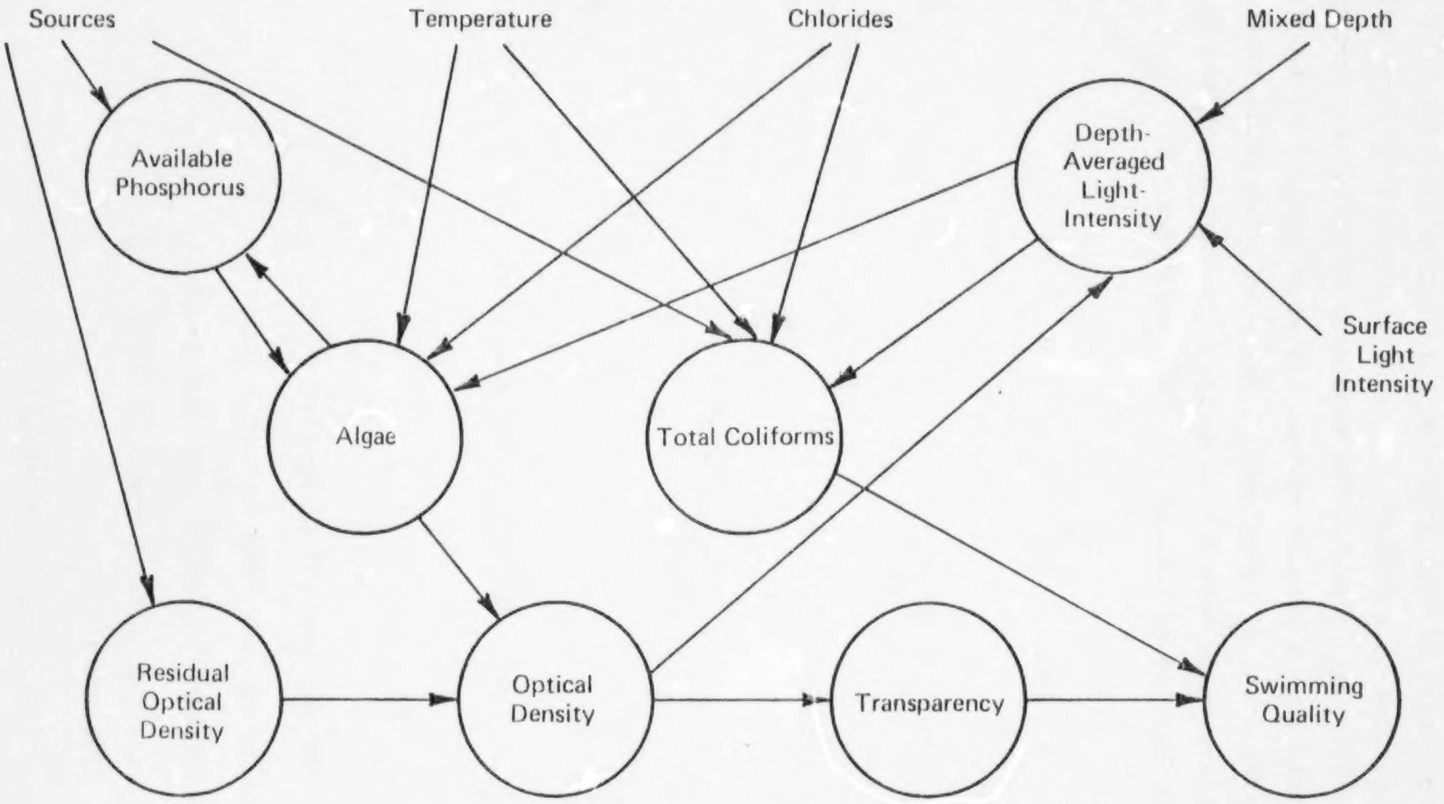

Sources
Temperature
Chlorides
Mixed Depth
Available Phosphorus
Depth-Averaged Light-Intensity
Surface Light Intensity
Algae
Total Coliforms
Residual Optical Density
Optical Density
Transparency
Swimming Quality

Figure D-3 Lower Charles River Model Control Pathways

For the purposes of this analysis, the original Charles River Basin model was simplified to a version of the upper Charles nutrient model. The objective here was to assess the magnitude of pollutant loading reductions necessary to protect against the water quality deterioration projected by the original basin model. The simplified model consisted of five equations which were solved serially to predict ambient concentrations as a function of loading and flow conditions:

$$Q_j = Q_{j-1} + 1.5 \frac{Q_m}{A_m} (A_{s_j} + \alpha_v A_{cj}) \quad (6)$$

$$t_j = 23.15 \frac{V_j}{Q_{j-1} + Q_j} \quad (7)$$

$$m_{ij} = m_{sij} + \alpha_p m_{cij} \quad (8)$$

$$J_{ij} = m_{ij} \left(\frac{1 - e^{-k_i t_j}}{k_i t_j}\right) + m_{ij-1} e^{-k_i t_j} \quad (9)$$

$$C_{ij} = 0.186 \frac{J_{ij}}{Q_j} \quad (10)$$

C_{ij} = mg/l; for coliforms/100 ml, multiply Equation (10) by 10^8.

where

Q_j = stream flow out of section j (cfs);

Q_{j-1} = stream flow into section j (cfs);

Q_m = stream flow at Waltham USGS gauge (cfs);

A_m = drainage area upstream of Waltham gauge (acres) = 102,400 acres;

A_{sj} = separate storm drainage to section j (acres);

A_{cj} = combined sewered drainage to section j (acres);

α_v = fraction combined sewer overflow volume retained;

t_j = travel time in section j (days);

V_j = freshwater volume in section j (million cu. ft.);

m_{ij} = inflow loading of pollutant i to section j (lb/day);

m_{sij} = loading from separate stormwater (lb/day);

m_{cij} = loading from combined sewer overflows (lb/day);

α_p = fraction pollutants retained in combined system;

k_i = decay coefficient for pollutant i (day^{-1}); and

m_{ij-1} = loading of pollutant i to section j from next upstream section (lb/day).

This model assumed the average runoff coefficient in the Basin drainage area to be 50% greater than that upstream from Waltham. It allowed stratification in the Basin to be considered by reducing the freshwater volume, V_j, in each section by the volume occupied by the stagnant salt water wedge. For any given set of flow, salinity and temperature conditions (which control t_j and k_i), phosphorus and bacterial concentrations in any section are linearly related to their respective loading rates into that and upstream sections. Parameter values for this model are summarized in Table D-3. Phosphorus concentrations in the Basin were reproduced well with a first-order decay coefficient of 0.1 day^{-1}, as they were in the upper sections of the river. Coliform decay coefficients varied linearly from 1 to 5 day^{-1} between seawater concentrations from 0 to 100%. Volumes were adjusted according to depth of salt wedge penetration. Concentrations of coliform bacteria in the Charles River Basin are higher at high flow rates than at low. The 1974 DWPC surveys indicated coliform concentrations throughout the Basin between 10^3 and 10^4/100 ml at low flow (34 cfs at USGS Waltham gauge) and between 10^4 and 10^5/100 ml at a more nearly average flow (205 cfs at Waltham). This occurs for three principal reasons: average detention times are longer at low flows, longer time for decay more than offsetting the reduced dilution; the increased salinity in the Basin during low flow periods results in a considerably higher coliform decay coefficient (bacterial

TABLE D-3

CHARLES RIVER BASIN MODEL PARAMETER VALUES

Original Segment, j	A_{sj}	A_{cj}	Max. Ave. Depth (ft)	Surface Area (10^6 ft^2)	Max. Volume (10^6 ft^3)
1	1,300	-	5.0	0.74	3.7
2	1,500	-	6.0	1.70	10.2
3	1,740	-	7.0	0.80	5.6
4	545	-	9.0	0.98	8.8
5	580	-	9.0	0.85	7.6
6	330	350	11.8	1.15	13.6
7	350	400	11.0	1.25	13.7
8	672	203	10.0	1.19	11.9
CR Section 7	7,017	953		8.66	75.1
9	4,630	240	8.0	1.35	10.8
10	7,013	2,470	12.0	3.80	45.6
11	-	410	17.0	10.00	170.0
12	-	200	20.0	2.85	57.0
CR Section 8	11,643	3,320		18.00	283.4

concentrations, therefore, will increase from those at present after the sea water intrusion is eliminated from the Basin); and there are presumably fewer combined sewer overflows during dry periods.

Some indication of the variability of bacterial concentrations with rainfall events can be obtained from the 1971 coliform data presented in Figure D-4. Streamflow at Waltham during the period displayed ranged generally between 50 and 70 cfs. DWPC coliform data show typically lower concentrations, partially because DWPC reports cross-sectional geometric means, whereas the Process Research data are arithmetic means. Also, the tide gate repairs between 1971 and 1974 would be expected to result in fewer combined sewer overflows and lower real coliform concentrations in 1974. Coliform concentrations projected by the Basin model for the end of Charles River water quality for section C7 and midway through section C8 are displayed also on Figure D-4 for the year 1970 coliform loadings and the following representative 1971 conditions:

Avg. flow at USGS Waltham gauge	60 cfs
Maximum freshwater layer depth	10 feet
Decay coefficient, Section 7	1.5 day^{-1}
Decay coefficient, Section 8	3.0 day^{-1}

D.3 Boston Harbor Coliform Model

A much simplified version of the Hydroscience steady-state Boston Harbor model was developed for this analysis. The Hydroscience model (1971) results in a matrix of linear algebraic equations of the form:

$$\begin{array}{lcl} a_{11}L_1 + a_{13}L_2 + a_{13}L_3 + \dots & = & C_1 \\ a_{21}L_1 + a_{22}L_2 + a_{23}L_3 + \dots & = & C_2 \\ \quad\vdots & & \vdots \\ a_{n1}L_1 + a_{n2}L_2 + a_{n3}L_3 + \dots & = & C_n \end{array} \qquad (11)$$

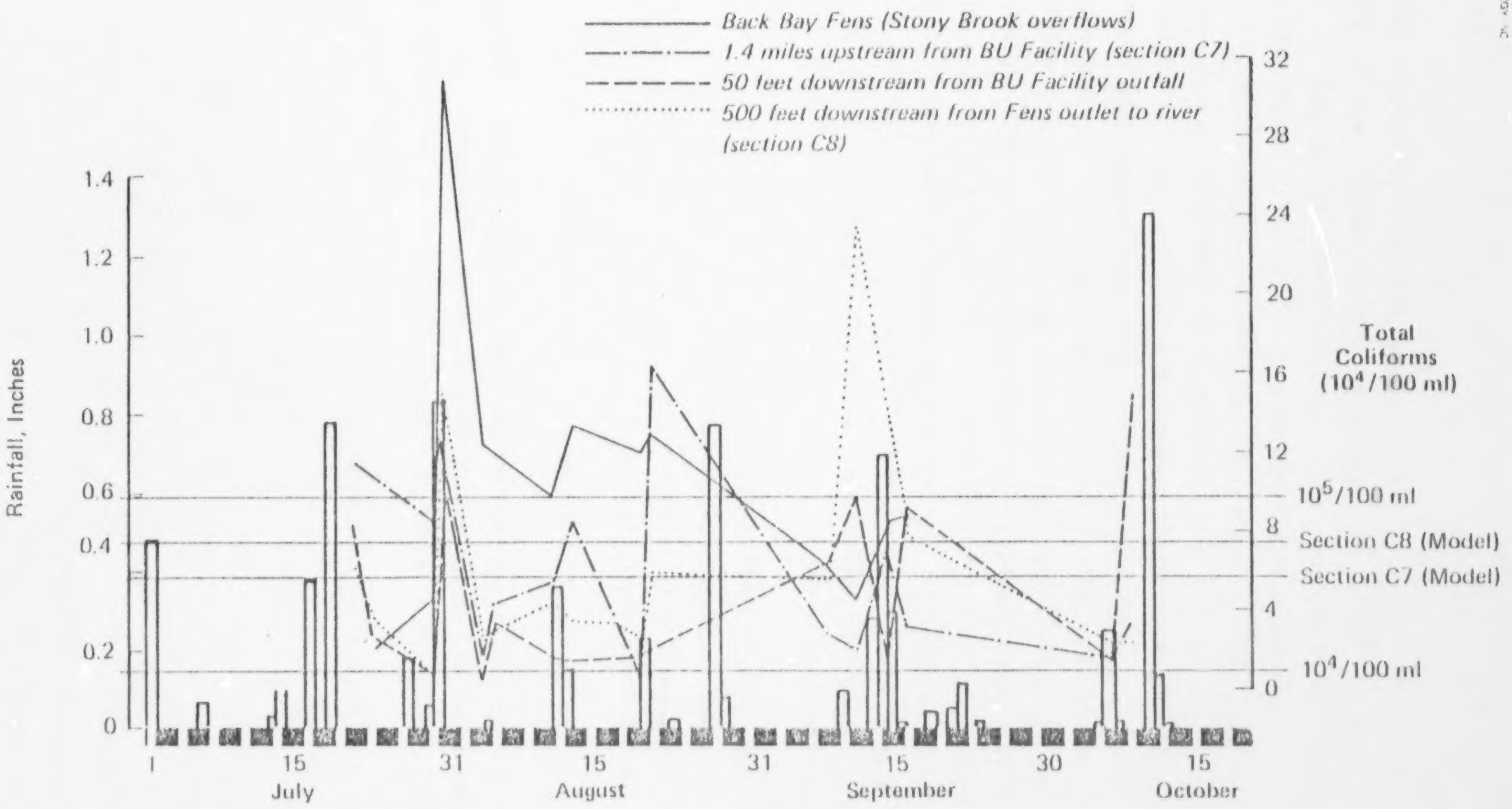


Figure D-4 Rainfall and Coliforms in Charles River Basin (Process Research, Inc. 1971) where

C_i = coliform concentration at location i (per 100 ml);

L_j = coliform discharge at location j (lb/day); and

a_{ij} = transfer coefficient relating contribution of load L_j to coliform concentration C_i.

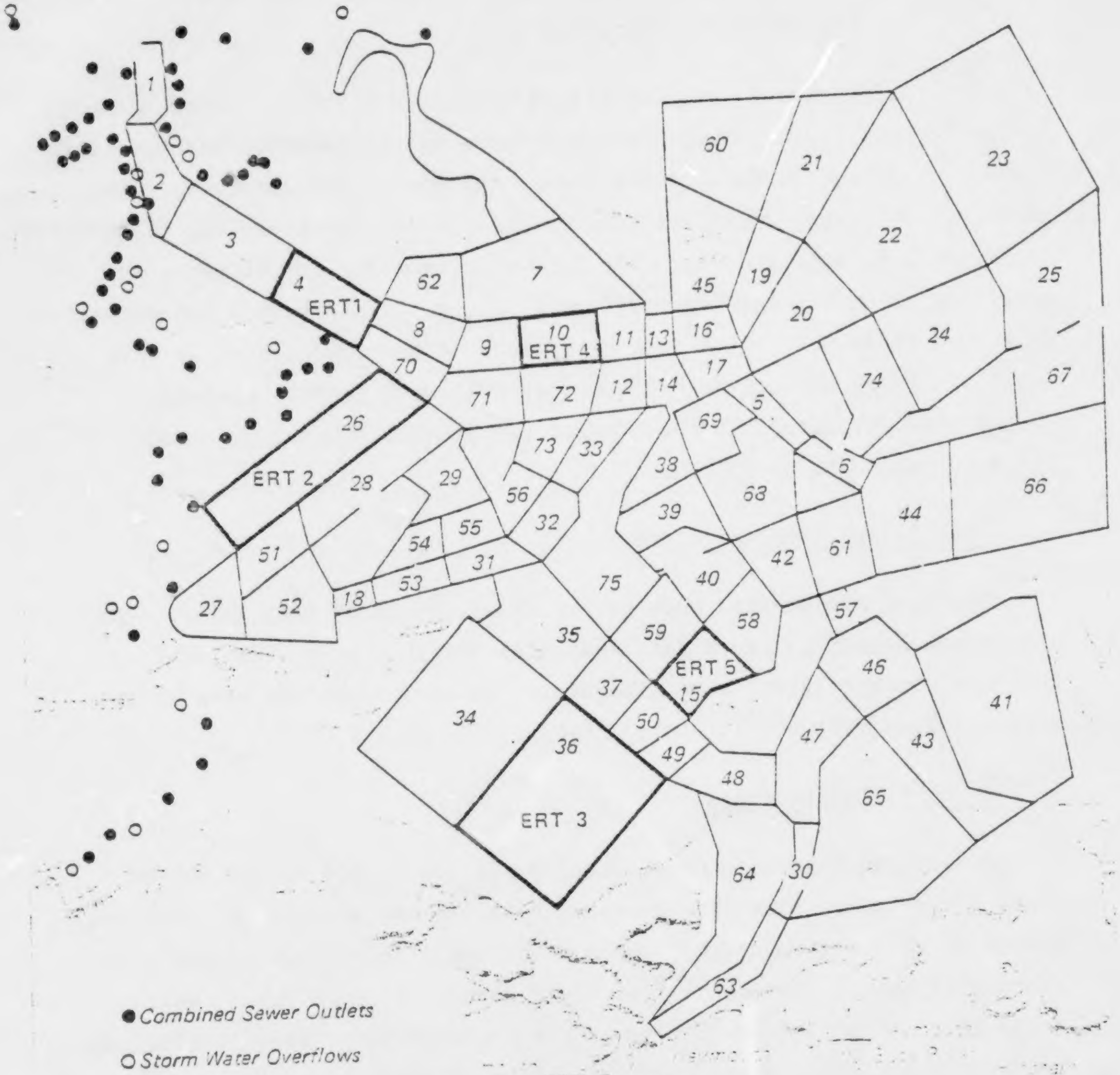
For this analysis, only five locations were assumed: Inner Harbor; Dorchester Bay; Quincy Bay; President Roads (Outer Harbor); and Nantasket Roads (Nut Island Outfall). The model, therefore, reduced to a system of only five linear equations (the original Hydroscience model, illustrated in Figure D-5, employed 76). The matrix of transfer coefficients was developed using the assumed coliform discharges and observed concentrations listed in Table D-4. With some exceptions, the values listed in this table are those assumed by Hydroscience (although several arithmetic errors were corrected) in their model calibration and verifications. The exceptions are as follows.

Deer Island Effluent, 1968

Hydroscience assumed much better chlorination of Deer Island than the Boston Harbor coliform data indicates for this year. Effluent coliform concentrations were, therefore, assumed to be the same as the unchlorinated effluent in winter, 1969.

Inner Harbor Loadings

Hydroscience added unnamed loadings of 100 to 250 lb/day to the Inner Harbor to achieve the necessary coliform concentrations. The only source of this magnitude that could exist would be the raw sewage plus stormwater runoff from the entire Inner Harbor tributary area, which could be about 80 lb/day (ten times the combined sewer overflow loadings in Table 5-3). This might result if all tide gates were missing or open and tributary sewer inverts were below high tide, which did seem to be the situation in 1967 through 1969. A constant 80 lb/day Inner Harbor load was, therefore, used in place of the Hydroscience assumptions. By 1973, however, these tide gates were presumably repaired, and the Inner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ERT 3
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Combined Sewer Outlets
Storm Water Overflows

Figure D-5 Hydroscience - 76-Section Model

TABLE D-4

COLIFORM DISCHARGE AND CONCENTRATION ASSUMPTIONS

Sources	Summer 1967			Summer 1968			Summer 1969			Winter 1969			Summer 1973
	MGD	Coli/100 ml	lb/day	MGD	Coli/100 ml	lb/day	MGD	Coli/100 ml	lb/day	MGD	Coli/100 ml	lb/day	lb/day
Deer I. Effluent	196	6×10^7	960	280	10^7	233	278	10^3	0.03	278	10^7	232	0.03
Deer I. Sludge	-	-	-	0.2	3×10^8	5.0	0.2	10^8	1.67	0.2	3×10^8	5	2.33
Nut I. Effluent	104	10^3	0.01	89	2×10^4	0.1	95	10^3	0.01	95	10^7	79	0.02
Nut I. Sludge	0.3	3×10^8	8.3	0.3	3×10^8	8.3	0.3	3×10^8	8.3	0.3	3×10^8	8.3	11.6
Moon I.	91	4×10^5	30	17	-	-	-	-	-	-	-	-	-
Inner H. Overflows	-	-	80	-		80	-	-	80	-	-	80	10
D. Bay Overflows	-	-	10	-		10	-	-	10	-	-	10	5
Charles River	154	2×10^4	0.2	154	2×10^4	0.2	154	2×10^4	0.2	200	2×10^4	0.33	-
Mystic River	20	3×10^4	0.05	20	3×10^4	0.05	20	3×10^4	0.05	30	3×10^4	0.07	-
Neponset River	62	1×10^4	0.05	62	1×10^4	0.05	62	1×10^4	0.05	85	1×10^4	0.07	-
Q. Bay Stormwater	-	-	0.35	-	-	0.35	-	-	0.35	-		0.35	-
Coliform Loadings													
Inner Harbor, L_1 =			80.25			80.25			80.25			80.40	10
Dorchester Bay, L_2 =			40.05			10.05			10.05			10.07	5
Quincy Bay, L_3 =			0.35			0.35			0.35			0.35	0.35
President Roads, L_4 =			968.3			246.3			10.00			245.3	13.96
Nantasket Roads, L_5 =			0.01			0.1			0.01			79	0.02
Coliform Concentrations (Log Mean): per 100 ml													
Inner Harbor C_1 =			40,000			10,000			10,000			-	1,000
Dorchester Bay C_2 =			15,000			1,000			1,000			-	700
Quincy Bay C_3 =			500			20			200			300	-
President Roads C_4 =			40,000			15,000			1,000			5,000	-
Nantasket Roads C_5 =			5,000			1,000			300			7,000	-

Harbor load was reduced to 10 lb/day (the estimated stormwater and combined sewer overflow loading in Table 5-3). Coliform data from 1973 indicates an order of magnitude concentration reduction from previous years.

Dorchester Bay

An additional source of coliform from combined sewer overflows and stormwater runoff was added to Dorchester Bay, based upon estimates in Table 5-3. The 1973 values were reduced to one-half those in previous years due to the elimination of sea water intrusion to the Dorchester Interception after tide gate repairs.

Quincy Bay

A coliform source due to stormwater runoff was added to Quincy Bay, again from the estimates in Table 5-3.

The resulting model which appears to represent the available data is:

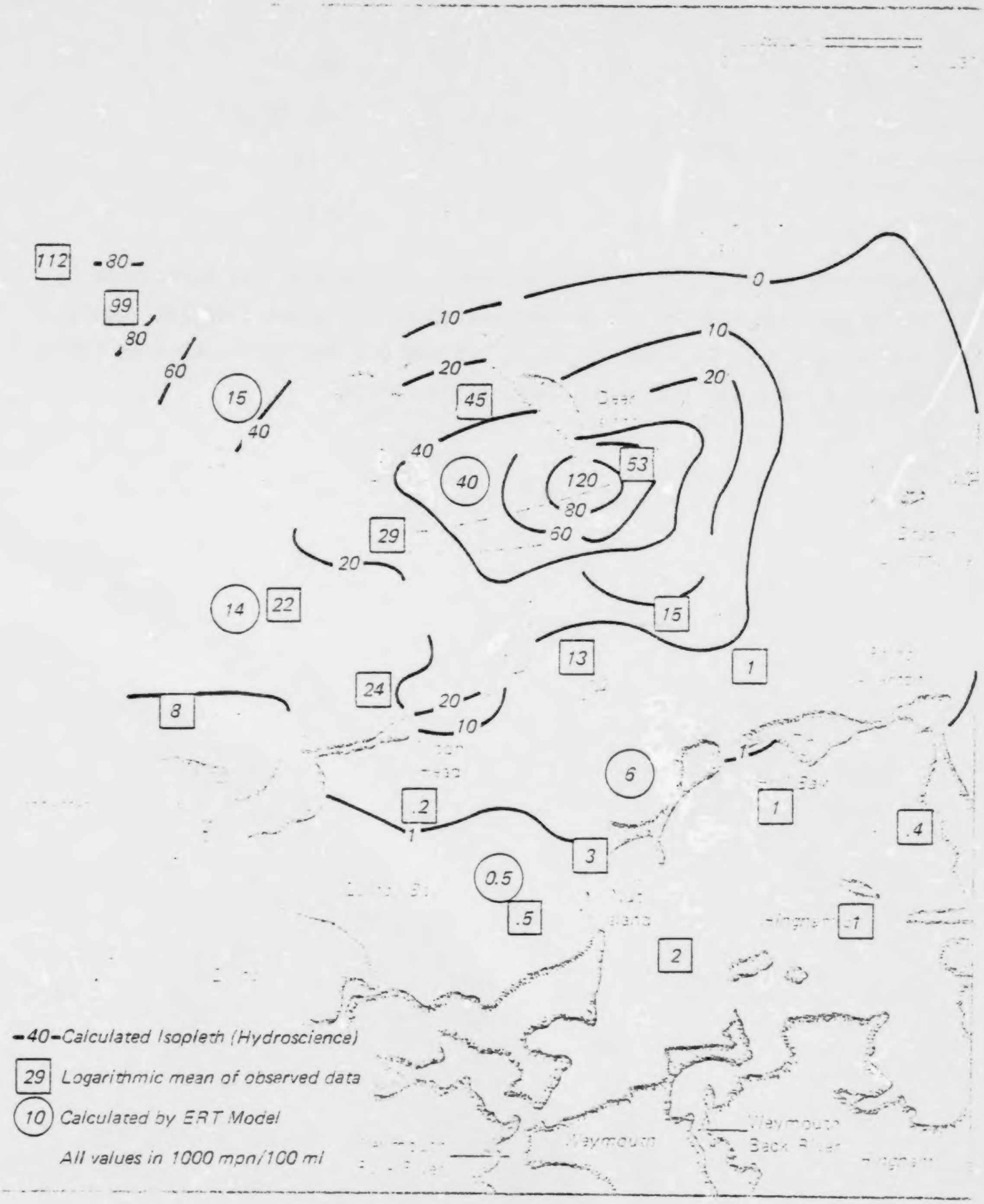
$$\begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{pmatrix} = \begin{pmatrix} 125 & 8 & 0 & 5 & 0 \\ 10 & 100 & 0 & 10 & 0 \\ 0 & 1 & 100 & 0.5 & 10 \\ 10 & 20 & 1 & 40 & 5 \\ 10 & 0 & 10 & 5 & 8 \end{pmatrix} \cdot \begin{pmatrix} L_1 \\ L_2 \\ L_3 \\ L_4 \\ L_5 \end{pmatrix} \qquad (12)$$

For reference, the load and concentration locations in this simplified model can be associated with Hydroscience segments as follows:

	Hydroscience Segment(s)
C_1	4
C_2	26
C_3	36
C_4	10
C_5	15

L_1	1, 2, 3, 4
L_2	26, 27
L_3	34, 36
L_4	13
L_5	15

Coliform concentrations in Boston Harbor as observed, as calculated by the Hydroscience model and as calculated by the simplified ERT model, are displayed in Figures D-6, D-7, D-8 and D-9 for the summers of 1967, 1968, 1969 and the winter of 1969, respectively.


112
-80-
99
80
60
15
40
10
0
10
20
20
45
Deer
40
40
120
53
80
60
29
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14
22
15
13
1
24
8
20
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6
.2
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1
1
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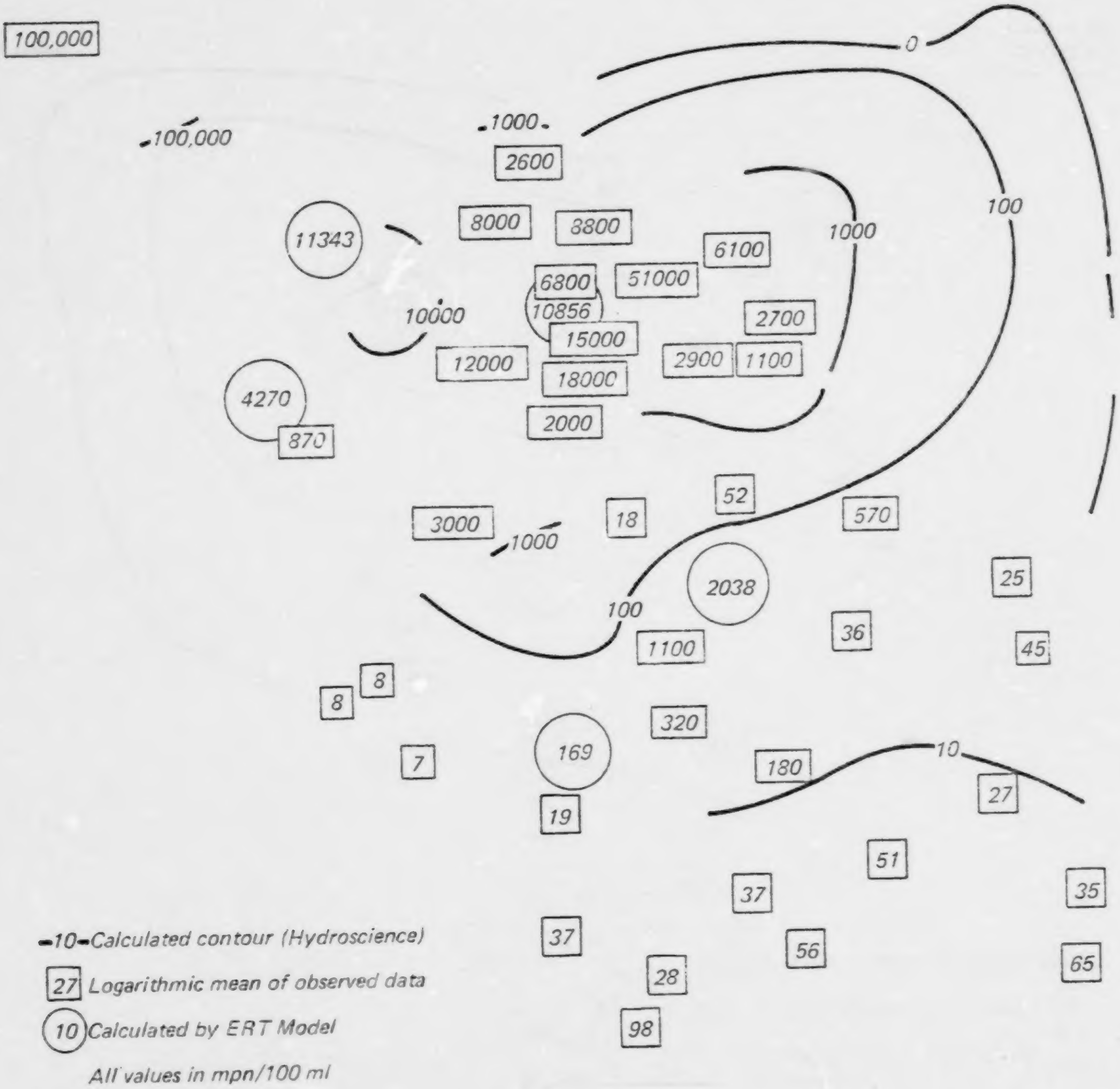
3
0.5
.5
.1
2
Weymouth
Weymouth Back River
Hingham
-40- Calculated Isopleth (Hydroscience)
29 Logarithmic mean of observed data
10 Calculated by ERT Model
All values in 1000 mpn/100 ml

Figure D-6 Total Coliform Comparisons - Summer 1967

D-22


100,000
100,000
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0
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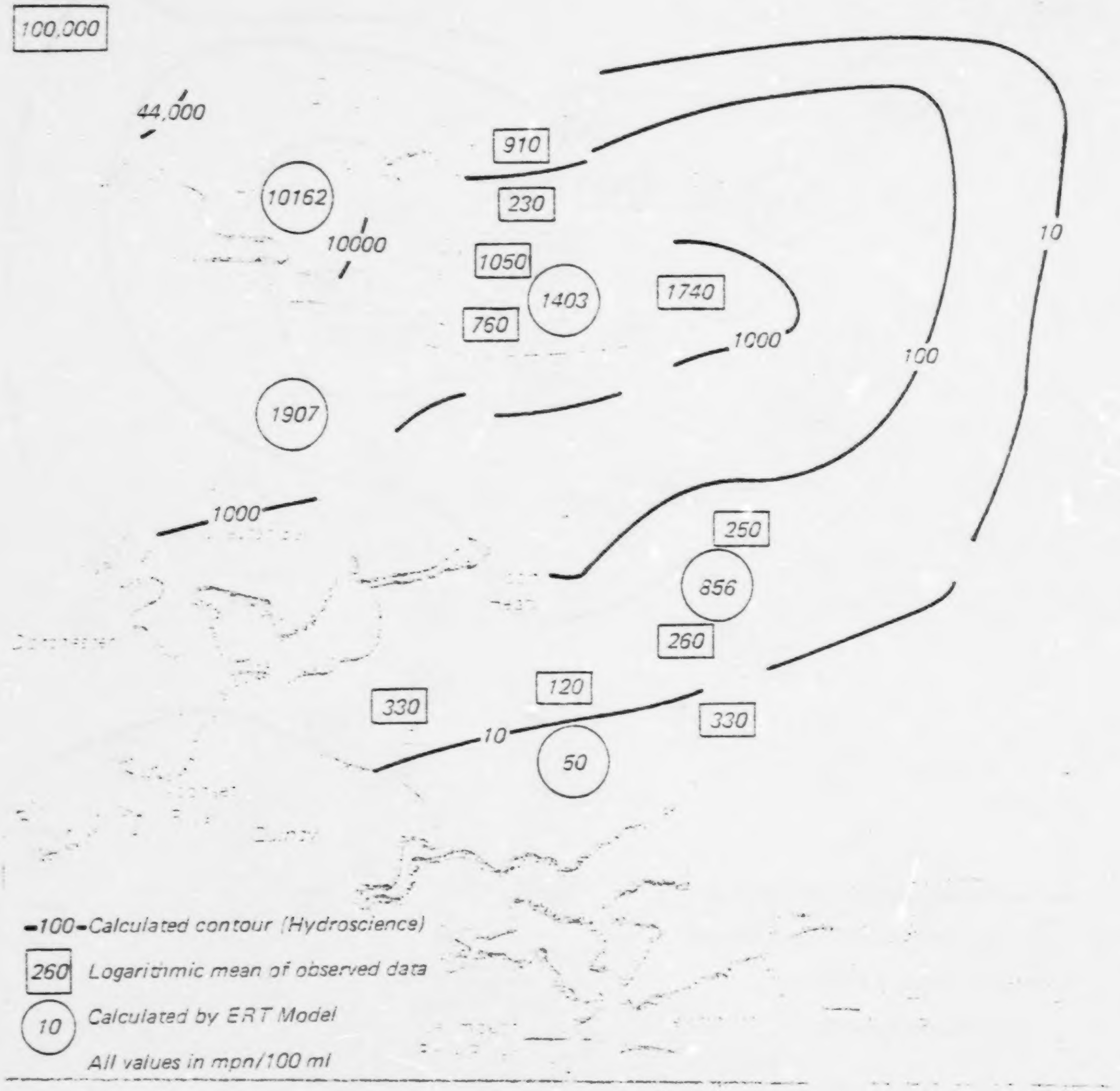
8000
8800
11343
6100
1000
100
6800
51000
10856
10000
15000
2700
12000
2900
1100
18000
4270
870
2000
52
570
3000
18
1000
2038
25
100
36
1100
45
8
8
320
7
169
10
180
27
19
51
37
35
37
56
65
28
98
-10-Calculated contour (Hydroscience)
27 Logarithmic mean of observed data
10 Calculated by ERT Model
All values in mpn/100 ml

Figure D-7 Total Coliform Comparisons - Summer 1968

11157


100,000
44,000
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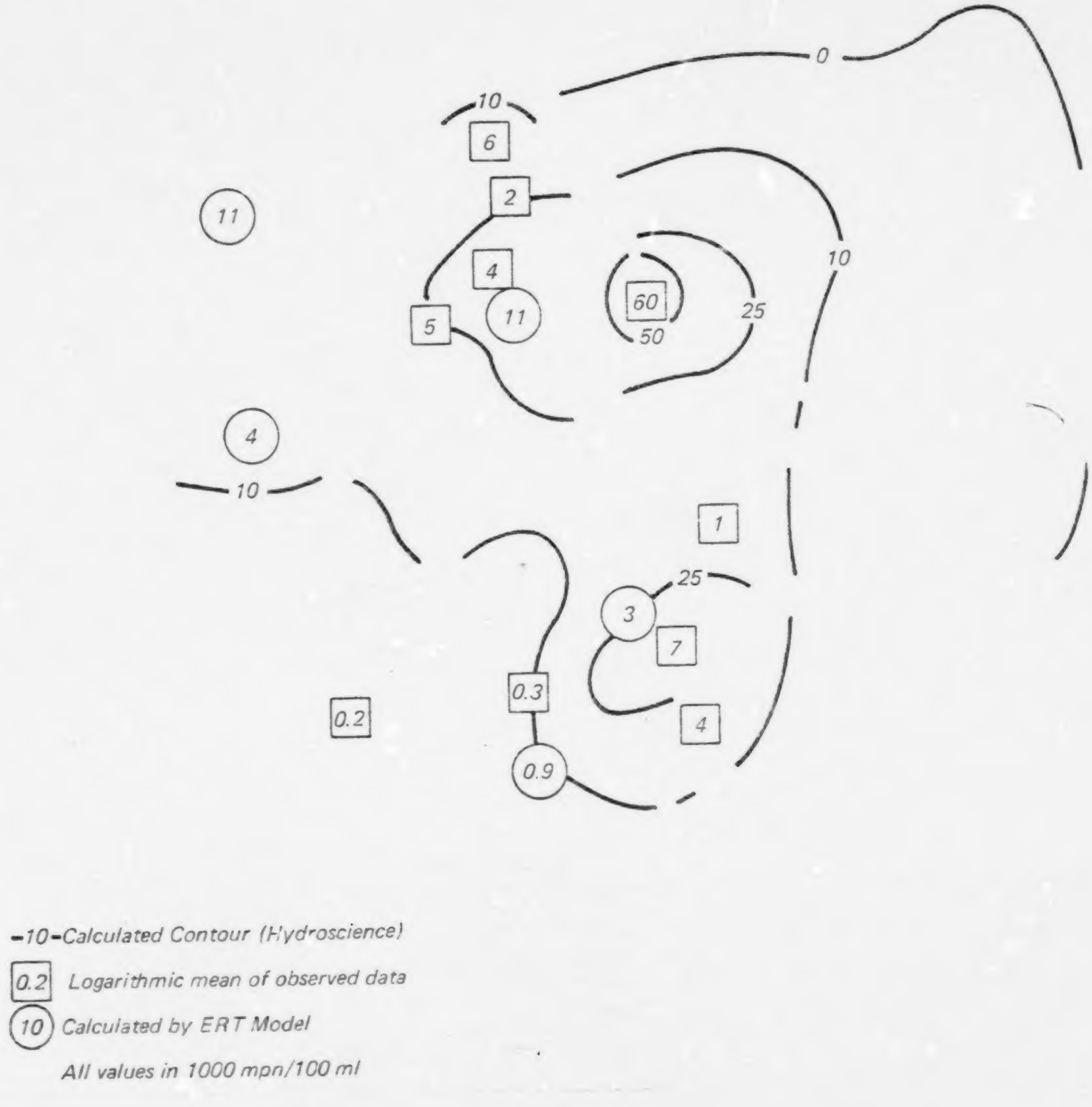
230
10162
10000
1050
1403
1740
760
1000
1907
10
100
1000
250
856
260
120
330
330
10
50
-100- Calculated contour (Hydroscience)
260 Logarithmic mean of observed data
10 Calculated by ERT Model
All values in mpn/100 ml

Figure D-8 Total Coliform Comparisons - Summer 1969


0
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11
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4
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7
0.3
0.2
4
0.9
-10-Calculated Contour (Hydroscience)
0.2 Logarithmic mean of observed data
10 Calculated by ERT Model
All values in 1000 mpn/100 ml

Figure D-9 Total Coliform Comparisons - Jan, Feb, Mar 1969

APPENDIX E

STREET CLEANING DYNAMICS

APPENDIX E

STREET CLEANING DYNAMICS

The following approach was used to examine the potential impact of street cleaning upon pollutant loadings in urban runoff. The variables used were:

X = accumulated material on streets (pounds/acre);

t_D = antecedent dry weather period (days);

k = effective street cleaning rate $(\text{days})^{-1}$; and

S = accumulation rate (pounds/acre-day).

Assuming that the street cleaning process is first order in the amount of X, a mass balance during a dry weather period gives the following differential equation:

$$\frac{dX}{dt} = S - kX \tag{1}$$

The boundary condition is:

$$X = X_0 \ @ \ t = 0 \tag{2}$$

where t = 0 at the end of the previous storm. Integration of Equation (1) gives:

$$\int_{X_0}^{X_{t_D}} \frac{dX}{S - kX} = {}_{0}^{t_D} dt \tag{3}$$

$$X_{t_D} = \frac{S}{k} + (X_0 - \frac{S}{k}) e^{-kt_D} \tag{4}$$

Over the period t_D, the total amount of material removed by street cleaning is:

$$M_S = \int_0^{t_D} k\,X\,dt \qquad (5)$$

$$= St_D + \left(X_0 - \frac{S}{k}\right)\left(1 - e^{-kt_D}\right) \qquad (6)$$

Removal efficiency, expressed as a fraction of the total accumulation rate, is given by:

$$\alpha_S = \frac{M_S}{St_D} = 1 + \left(\frac{X_0}{St_D} - \frac{1}{kt_D}\right)\left(1 - e^{-kt_D}\right) \qquad (7)$$

or

$$\alpha_R = 1 - \alpha_S = \left(\frac{1}{kt_D} - \frac{X_0}{St_D}\right)\left(1 - e^{-kt_D}\right) \qquad (8)$$

where

α_S = fraction of materials removed by cleaning; and

α_R = fraction of materials removed by runoff.

In order to apply these equations, the initial condition, X_0, or the ratio X_0/St_D must be estimated. If η_R is defined as the fraction of accumulated materials washed off during a given storm event, a steady-state materials balance gives:

$$(X_0 + St_D\alpha_R)\,(1 - \eta_R) = X_0 \qquad (9)$$

$$\frac{X_0}{St_D} = \frac{\eta_R}{1 - \eta_R}\,\alpha_R \qquad (10)$$

Substituting into Equation (8):

$$\alpha_R = \left(\frac{1}{kt_D} - \frac{\eta_R}{1 - \eta_R}\,\alpha_R\right)\left(1 - e^{-kt_D}\right) \qquad (11)$$

Solving for α_R explicitly:

$$\alpha_R = \frac{1}{kt_D \left(\frac{1}{\eta_R} + \frac{1}{1 - e^{-kt_D}} - 1 \right)} \tag{12}$$

The η_R factor depends upon storm intensity, storm duration and assumed washoff dynamics. The HEC model STORM distinguishes two types of materials and corresponding washoff functions.

For soluble components:

$$\eta_R = 1 - e^{-4.6\ iCt_s} \tag{13}$$

For solids:

$$\eta_R = (1 - e^{-4.6\ iCt_s})\ (0.057 + 1.4\ (iC)^{1.1}) \tag{14}$$

where

i = storm intensity (in/hr);

t_s = storm duration (hours); and

C = runoff coefficient.

The second term in Equation (14) is the so-called "availability factor" for solids washoff and was added because Equation (13) didn't fit the limited amount of data available.

In order to apply Equation (12) to a given area and averaging period, the distribution of storm intensities, durations and antecedent dry-weather periods must be taken into account. One approach would be to simulate the period of meteorological record for a number of different values of k. Equation (12) could then be adapted to the simulation results by adjusting η_R and/or t_D. This procedure has been put into effect using Boston meteorology ($\bar{i}$ = 0.08 in/day, $\bar{t}_s$ = 7 hours, $\bar{t}_D$ = 4 days) and for each assumed washoff function (Equations (13) and (14)). In each case, reasonable agreement between simulations and predictions of Equation (12) has been achieved by fixing t_D at the average value (four days) and searching for the appropriate value of η_R by trial and error. Results are shown in Figure E-1. This procedure results in a value of 0.300 for η_R, if soluble component washoff dynamics are assumed (Equation (13)) and a value of 0.087 if suspended solid washoff dynamics are assumed (Equation (14)). Since η_R represents the average fraction of accumulated materials washed off per storm, results suggest that including the "availability factor" in the function for washoff dynamics substantially decreases the average washoff efficiency of storms and increases the average levels of accumulated materials on the streets. The differences between the two curves in Figure E-1 indicate that assessment of the effectiveness of street cleaning operations as a pollution control measure can be quite sensitive to the assumed washoff function.

Combining Equation (12) with the appropriate value of η_R gives the following equations which can be used as "production functions" for street cleaning in Boston under each washoff assumption.

For soluble components:

$$1 - \alpha_S = \frac{1}{4k\left(1 + \frac{1}{1 - e^{-4k}}\right)} \qquad (15)$$

For solids:

$$1 - \alpha_S = \frac{1}{4k\left(10.5 + \frac{1}{1 - e^{-4k}}\right)} \qquad (16)$$

The effective street cleaning rate, k, can be estimated as the product of frequency and efficiency:

$$k = f_S e_S \qquad (17)$$

where

f_S = cleaning frequency $(\text{day})^{-1}$; and

e_S = cleaning efficiency $(0 \leq e_s \leq 1.0)$

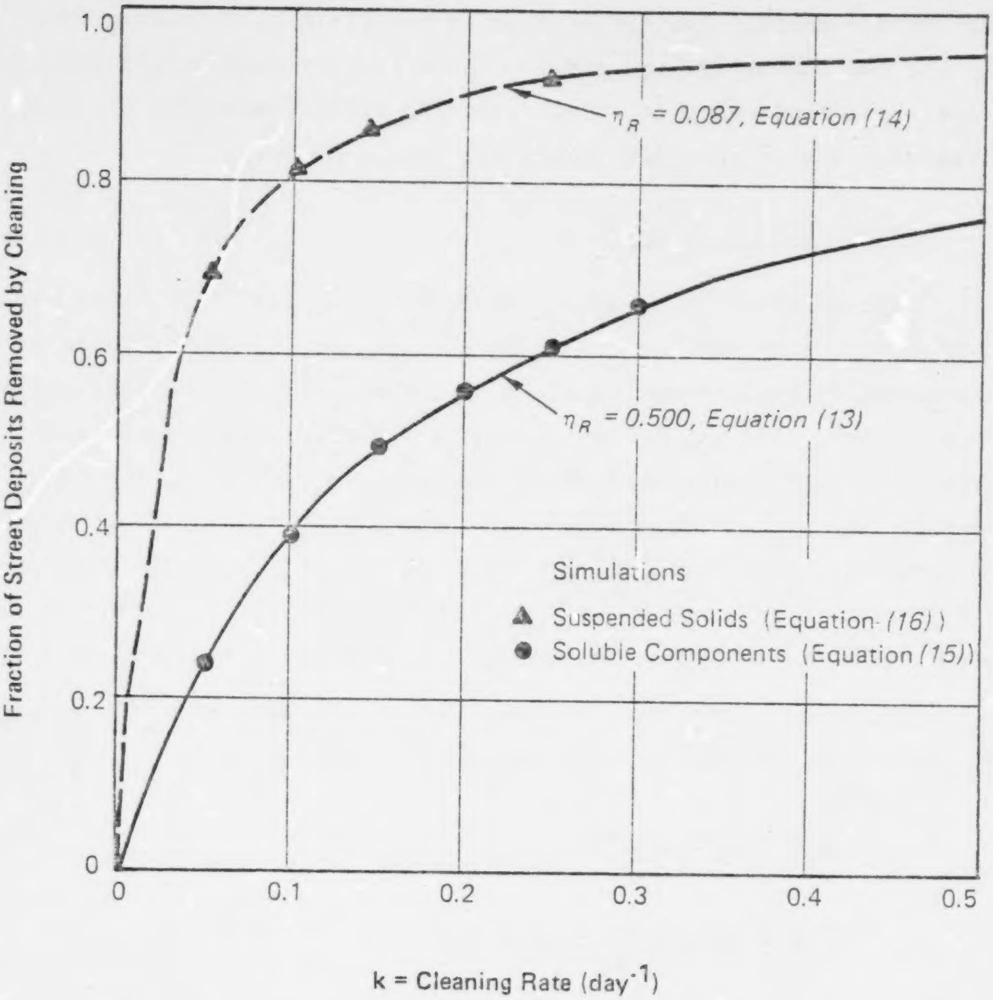

Figure E-1 Net Street Cleaning Efficiency versus Sweeping Rate for Two Assumed Washoff Formulations

Mechanical sweeper efficiencies have been shown to decrease with decreasing particle size. For a given frequency, the appropriate value of k for use in predicting the recovery of soluble components is probably less than the appropriate value in the case of solids. This would tend to further enhance the differences in net cleaning recoveries depicted by the two curves in Figure E-1. These results demonstrate quantitatively the dependence of street cleaning effectiveness on cleaning frequency and on the particulate fraction considered.

Street Cleaning Costs

Data on costs of street cleaning in U. S. cities is extremely variable. Heany and Nix (1977) have suggested the median value of data collected from 160 municipalities by the American Public Works Association (APWA), that is, $7 per curb-mile. Street cleaning equipment costs have been reported as $25,000 per machine for mechanical sweepers and $45,000 per machine for vacuum type cleaners (Hinkle 1977). Removal efficiencies for the former are about 50% overall and very low for the fine particle sizes (APWA 1977). Efficiencies for the latter have been reported to be in excess of 90% for all particle sizes (Horton 1976).

The following method has been used to estimate street cleaning costs. Curb length, in miles per acre, is estimated by:

Residential areas

$$G_R = 0.0782 - 0.06688\,(0.839)^{PD} \quad (18)$$

Commercial/Industrial areas

$$G_{C/I} = 0.0782 \quad (19)$$

Other

$$G_O = 0.0114 \quad (20)$$

Both types of equipment are estimated to travel at a net average speed of 1.5 miles of curb per hour and they are operated 16 hours per day, 8 months per year; operating and maintenance personnel are engaged in snow removal operations the remaining 4 months.

The capital cost of equipment is, thus:

Mechanical Sweepers

$$C_{MS} \text{ (\$/acre)} = 1042\ G\ f_S \qquad (21)$$

Vacuum Cleaners

$$C_{VC} \text{ (\$/acre)} = 1875\ G\ f_S \qquad (22)$$

Assuming the operating and maintenance costs are $7/curb-mile for both types of equipment, annual O&M costs are:

$$(O\&M)_S = 1073\ G\ f_S \qquad (23)$$

Since f_S equals k/e_S, Equations (21) and (22) become, if 50% and 90% are the respective removal efficiencies for the two types of equipment:

$$C_{MS} \text{ (\$/acre)} = 2084\ G\ k \qquad (24)$$

and

$$C_{VC} \text{ (\$/acre)} = 1893\ G\ k \qquad (25)$$

APPENDIX F

STORAGE/TREATMENT SYSTEMS OPTIMIZATION FOR STORM/COMBINED SEWERS

APPENDIX F

STORAGE/TREATMENT SYSTEMS OPTIMIZATION FOR STORM/COMBINED SEWERS

Simulations of various combinations of runoff storage and treatment capacities, with a STORM type of model using a 14-year meteorological record in the Boston area, were used to generate production functions of the Cobb-Douglas form:

$$Y_{ST} = \frac{E}{1-E} = aS^bT^g \qquad (1)$$

where

E = fraction of runoff captured and subsequently "treated" before discharge ($0 \leq E \leq 1.0$);

S = storage capacity, inches;

T = "treatment" capacity, in/day; and

a,b,g = empirical coefficients.

Specific input conditions to the simulation model, which was the South Boston runoff portion of the ERT Dorchester Bay Model, were:

Population density = 63 people/acre;

Area = 278 acres;

Infiltration Rate = 1000 gal/acre-day;

Domestic Sewage Flow = 100 gal/cap-day;

Total Dry Weather Flow = 2.03 mgd;

Total Dry Weather Flow = 0.28 in/day;

Runoff Coefficient = 0.80; and

Time of Concentration = 0.5 hour.

Since this model already contained an off-line storage subroutine, "treatment" was simulated by simply increasing interceptor carrying capacity. The default capacity, that is, zero treatment, for the combined sewer application was set equal to the average dry weather flow.

For the separate stormwater runoff application, interceptor capacity was set equal to dry weather flow for zero treatment, and only street surface solids were considered. Three versions of the production function, Equation (1), were developed. The first considered E to be the fraction of the runoff volume captured and "treated". The second and third considered E to be the fraction of soluble and suspended pollutants captured and treated according to the street surface wash-off formulations described respectively as Equations (13) and (14) in Appendix E. The three production functions which result are:

Volume capture function:

$$\frac{E}{1-E} = 18.41\, S^{0.934}\, T^{1.049} \qquad (2)$$

Soluble pollutant wash-off function:

$$\frac{E}{1-E} = 36.81\, S^{1.130}\, T^{0.583} \qquad (3)$$

Suspended pollutant wash-off function:

$$\frac{E}{1-E} = 23.93\, S^{1.098}\, T^{0.603} \qquad (4)$$

The cost of storage and treatment can be expressed:

$$Z_{ST} = c_S S + c_T T \qquad (5)$$

where:

Z_{ST} = combined annual cost of storage/treatment in \$/acre;

c_S = unit annual cost of storage, in \$/inch and

c_T = unit annual cost of treatment, in \$/inch/day.

The storage treatment optimization problem, then, is to minimize Equation (5), subject to the constraint represented by a rearrangement of Equation (1):

$$\frac{Y_{ST} S^{-b} T^{-g}}{a} \leq 1.0 \qquad (6)$$

This optimization problem can readily be transformed to the dual Geometric Programming problem:

$$(Z_{st})_{opt.} = \left(\frac{C_S}{\delta_1}\right)^{\delta_1} \left(\frac{C_T}{\delta_2}\right)^{\delta_2} \left(\frac{Y_{ST}}{a}\right)^{\delta_3} \qquad (7)$$

Subject to:

$$\begin{aligned} \delta_1 + \delta_2 \qquad &= 1.0 \\ \delta_1 \qquad -b\delta_3 &= 0 \\ \delta_2 -g\delta_3 &= 0 \end{aligned} \qquad (8)$$

The simultaneous Equations (8) are solved:

$$\delta_1 = \frac{b}{b+g} \qquad (9)$$

$$\delta_2 = \frac{g}{b+g} \qquad (10)$$

$$\delta_3 = \frac{1}{b+g} \qquad (11)$$

For the three production fuctions, the corresponding production function coefficients and dual problem δ-values are:

Washoff Formulation	a	b	g	δ_1	δ_2	δ_3
Runoff Volume, Equation (2)	18.41	0.934	1.049	0.471	0.529	0.504
Soluble Fraction, Equation (3)	36.81	1.130	0.583	0.660	0.340	0.584
Suspended Fraction, Equation (4)	23.93	1.098	0.603	0.646	0.354	0.588

In the dual Geometric Programming problem as posed, δ_1 and δ_2 are by definition equal to the respective fractions of the total optimal design cost that are apportioned to storage and treatment:

$$\delta_1 \equiv \frac{c_S S}{(Z_{ST})_{opt.}} \qquad (12)$$

$$\delta_2 \equiv \frac{c_T T}{(Z_{ST})_{opt.}} \qquad (13)$$

Thus, if pollutant concentrations are assumed to be distributed relatively evenly over the runoff period, that is, the volume capture formulation (Equation (2)), costs of the optimal combination would be relatively evenly distributed between storage and treatment. If either one of the first-flush wash-off formulations is assumed, however, roughly twice as much should be invested in storage as in treatment. It is important to note that these optimal cost distributions are completely independent of the unit costs of storage and treatment, but depend only upon the exponents of the production, or technological, function, Equation (1).

Unit cost estimates have been provided by Heaney et al. (1976) for various storage and treatment combinations. The estimates for treatment processes, however, seem too low by almost an order of magnitude. Costs for the Boston area, therefore, were developed from data presented in the EMMA study. The costs of the storage tanks listed in Table 5-3, EMMA Volume 7, can be described by the expression:

$$\text{Storage Capital Costs} = \$715\ (V,\ cf)^{0.72} \qquad (14)$$

If the average drainage area to each storage tank in a decentralized system is assumed to be 500 acres, the capital cost of storage can be approximated as:

$$\text{Storage Capital Costs (\$/acre)} = 26{,}800\ (S,\ in) \qquad (15)$$

Figure 9-3, Volume 2 of the EMMA study, was used to estimate treatment costs. For secondary treatment plants between about 7 mgd and 70 mgd, capital costs can be approximated as:

$$\text{Secondary Treatment} = \$1.4 \times 10^6\ (Q,\ mgd)$$

or

$$\text{Secondary Treatment (\$/acre)} = 37{,}760\ (T,\ in/day) \qquad (16)$$

From the same figure, Advanced Waste Treatment (AWT) capital costs can be approximated as:

$$\text{AWT} = \$2.45 \times 10^6 \text{ (Q, mgd)}$$

or

$$\text{AWT (\$/acre)} = 66{,}000 \text{ (T, in/day)} \cdot \qquad (17)$$

Primary treatment plants were estimated at one-third the cost of secondary treatment plants (see Kennedy Engineers draft final report, Figure 2-8).

Annual operation and maintenance costs for AWT plants were obtained from Figure 9-4, EMMA Volume 2, as:

$$\text{Annual AWT O\&M} = \$0.17 \times 10^6 \text{ (Q, mgd)}$$

or

$$\text{AWT O\&M (\$/acre-year)} = 4{,}500 \text{ (T, in/day)} \qquad (18)$$

O&M costs for secondary and primary treatment plants were assumed proportional to capital costs in the same ratio as AWT O&M to capital costs. Annual O&M costs for storage tanks alone were assumed to be one-fourth the O&M costs estimated for the combined sewer overflow detention and chlorination facilities in Table 5-6, EMMA Volume 7. This assumption results in estimated storage O&M costs of $640 per acre-inch of storage capacity. Storage and treatment cost estimates are summarized in Table F-1.

Since E represents the fraction of either runoff volume or pollutants captured and processed through the treatment plant, the fraction of pollutants removed can be described:

$$\alpha_{ST} = f_T E \qquad (19)$$

where

α_{ST} = overall fraction of pollutants removed; and

f_T = fraction removed in treatment process

TABLE F-1

STORAGE AND TREATMENT COST ESTIMATES

	Annual Costs			Unit Costs	
Unit Process	Amortized Capital	O&M	Total Cost	c_S	c_T
Storage	\$2,300 S	\$ 640 S	\$ 2,940 S	\$3,000	-
Primary Treatment	\$1,080 T_P	\$ 860 T_P	\$ 1,940 T_P	-	\$ 1,900
Secondary Treatment	\$3,240 T_S	\$2,570 T_S	\$ 5,810 T_S	-	\$ 5,800
AWT	\$5,670 T_{AWT}	\$4,500 T_{AWT}	\$10,170 T_{AWT}	-	\$10,200

The production function, Y_{ST}, can then be written:

$$Y_{ST} = \left(\frac{E}{1 - E}\right) = \left(\frac{\alpha_{ST}}{f_T - \alpha_{ST}}\right) \qquad (20)$$

and the optimal storage/treatment cost, Equation (7), can be expressed in terms of the overall pollution control effectiveness:

$$(Z_{ST})_{opt.} = k \left(\frac{\alpha_{ST}}{f_T - \alpha_{ST}}\right)^{\delta_3} \qquad (21)$$

where

$$k = \left(\frac{c_S}{\delta_1}\right)^{\delta_1} \left(\frac{c_T}{\delta_2}\right)^{\delta_2} \left(\frac{1}{a}\right)^{\delta_3} \qquad (22)$$

For the three treatment processes and three wash-off formulations, the parameter values in Equation (21) are summarized in Table F-2.

Equation (21) is plotted in Figure F-1 as annual costs versus pollutant control effectiveness for various combinations of treatment process and wash-off formulations. The optimal ratio of storage (inches) to treatment capacities (in/day) can be determined by the quotient of Equation (12) and Equation (13):

$$\left(\frac{S}{T}\right)_{opt.} = \frac{\delta_1}{\delta_2} \frac{c_T}{c_S} \qquad (23)$$

For the various combinations of treatment process and wash-off formulations considered, optimal storage/treatment ratios are listed in Table F-3.

If a first flush phenomenon is assumed, the optimal ratio of storage/treatment capacities will be twice that without the first flush assumption. Also, this ratio will increase more than five-fold between primary treatment and AWT.

TABLE F-2

TREATMENT PROCESSES

Wash-off Formulation	Primary			Secondary			AWT		
	k	f_T	δ_3	K	f_T	δ_3	k	f_T	δ_3
Runoff Volume Equation (2)	1,084	0.4	0.504	1,956	0.85	0.504	2,636	0.975	0.504
Soluble Fraction Equation (3)	591	0.4	0.584	863	0.85	0.584	1,046	0.975	0.584
Suspended Fraction Equation (4)	740	0.4	0.588	1,099	0.85	0.588	1,342	0.975	0.588

TABLE F-3

OPTIMUM RATIOS* OF STORAGE CAPACITIES TO TREATMENT CAPACITIES

Wash-off Formulation	Primary	Secondary	AWT
Volume Capture Euation (2)	0.74	2.24	3.95
Soluble Fraction Equation (3)	1.60	4.89	8.60
Suspended Fraction Equation (4)	1.50	4.59	8.07

*Units are days.

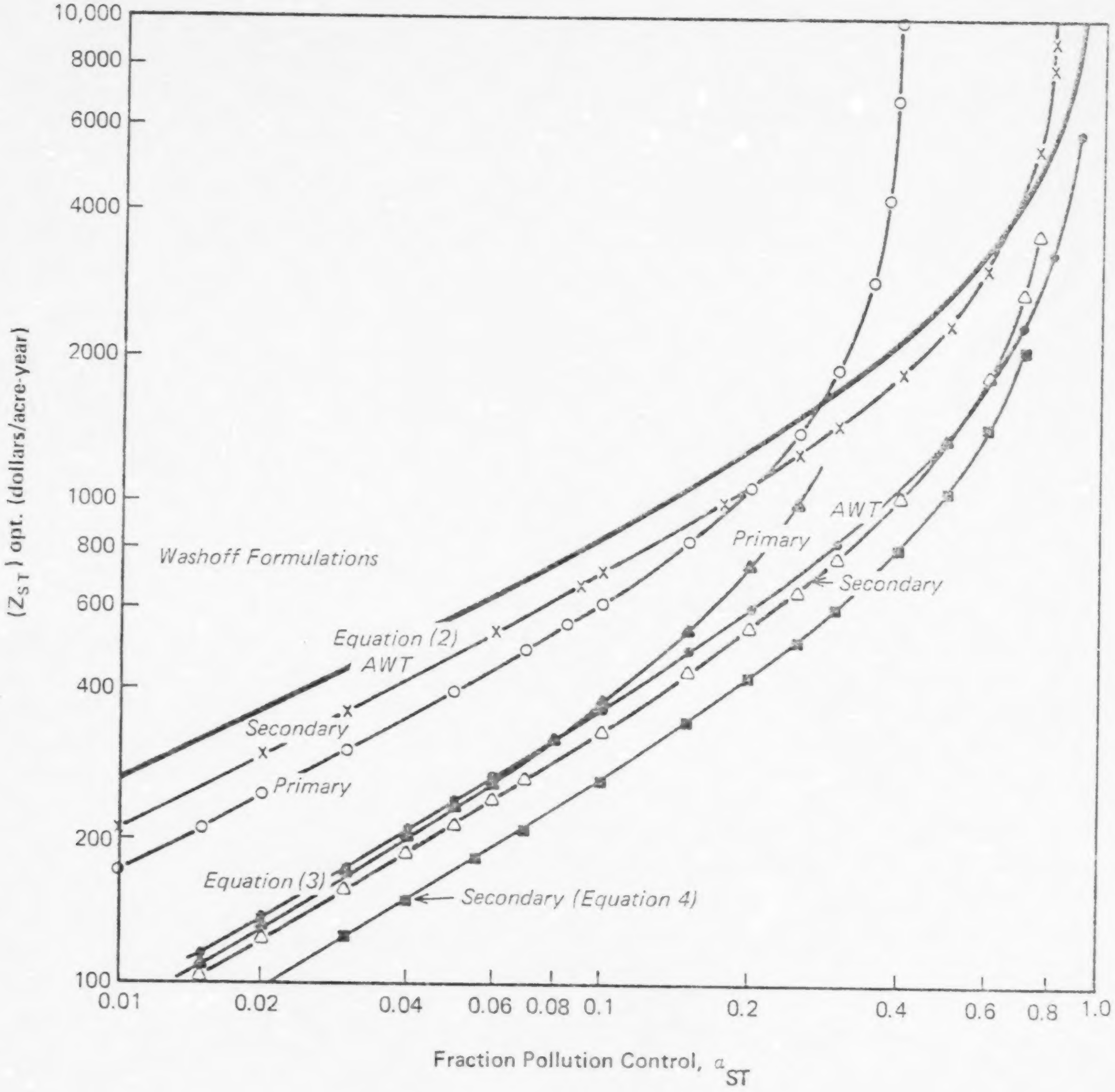

Figure F-1 Annual Costs versus Pollutant Control Effectiveness

APPENDIX G

AUTOMATED FLUSHING OF COMBINED SEWER SYSTEMS

APPENDIX G

AUTOMATED FLUSHING OF COMBINED SEWER SYSTEMS

A pipe-by-pipe analysis of predicted solids deposition rates in the Dorchester and South Boston sewer systems was performed to develop generalized solids distribution functions. These distribution functions are of the form:

$$Y_F = X_F^n \tag{1}$$

where:

Y_F = fraction of total solids deposited in X pipe components;

X_F = fraction of total pipe components;

n = empirical coefficient.

For this analysis, a pipe component was a length of pipe of constant geometry, slope and flow. The mean length of the 2,666 components analyzed was 192 feet. Some of the data from Dorchester and South Boston are displayed in Figure G-1. The South Boston system is almost totally combined: 95.6% of all laterals are combined, and the 4.4% that are separate sanitary laterals all discharge to combined trunk sewers. In Dorchester, however, only 38.6% of all laterals are combined, and 61.4% are separate sanitary laterals; all discharge to combined trunk sewers which discharge to the combined Dorchester Intercepter. These distributions of service types (sanitary versus combined) strongly influence the solids distribution throughout the system. Design practice for separate sanitary sewers typically results in relatively little deposition of solids during dry weather. Combined sewers, which are designed more for wet weather flows, experience considerably greater deposition rates during dry weather. The result is that solids from the separate sanitary sewered areas will more likely be deposited in a relatively small fraction of the total pipe components, that is, in the downstream combined trunks and/or interceptors; solids from the completely combined areas will more likely be deposited in a much larger fraction of the total pipe components, that is, throughout the upstream

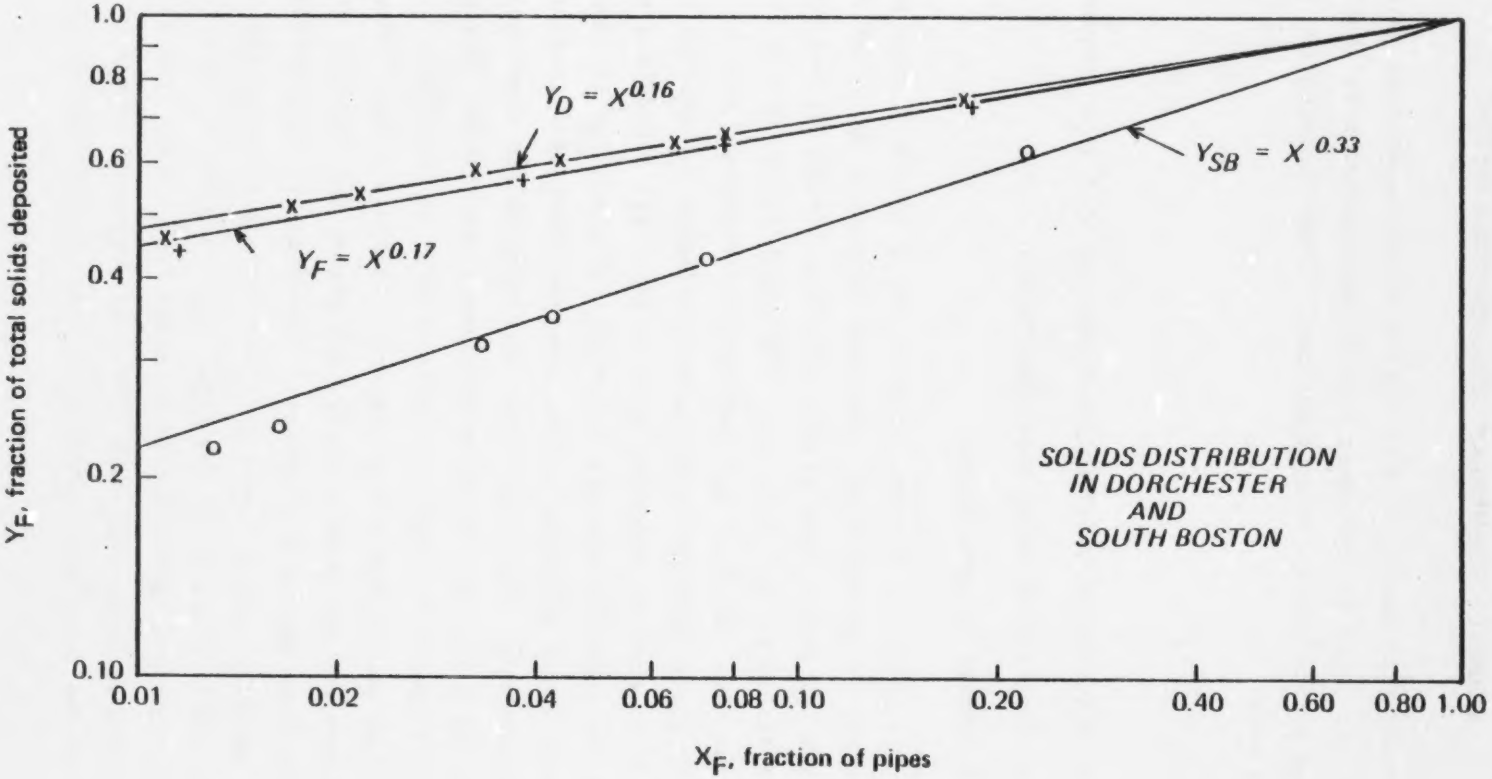

Figure G-1 Solids Distribution in Dorchester and South Boston combined laterals. This influence on the relative solids distributions in the Dorchester and South Boston systems is shown in Figure G-1.

For these systems, this influence can be accounted for in the exponent, n, in Equation (1) by:

$$n = \frac{1}{2.8f_c + 8.4f_s} \qquad (2)$$

where

f_c = a fraction of laterals that are combined;

f_s = a fraction of laterals that are separate sanitary.

Equation (1) thus becomes:

$$Y_F = X_F^{\frac{1}{2.8f_c + 8.4f_s}} \qquad (3)$$

This equation is also plotted in Figure G-1 for the Dorchester, South Boston and total sewerage systems, using the f_c and f_s values listed below.

Sewer System	f_c	f_s
Dorchester	0.386	0.614
South Boston	0.956	0.044
Total	0.455	0.545

From data developed for these sewer systems and plotted in Figure G-2, the capital cost estimates (ENR = 2,200) for automated sewer flushing networks with greater than 200 flushing stations can be represented by the equation:

$$C_F = \$18,000\ F^{0.875} \qquad (4)$$

where

F = the number of flushing stations per network.

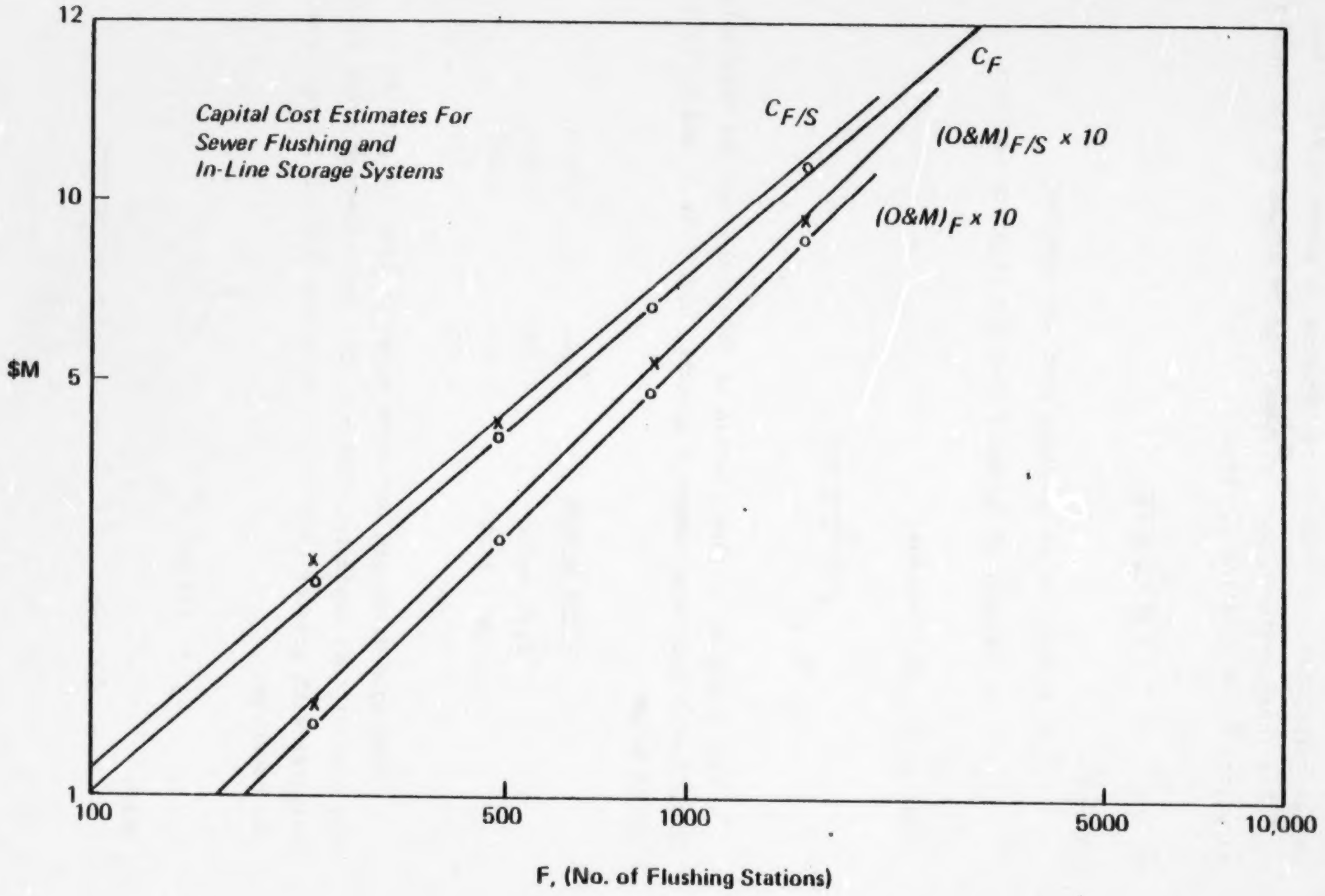

Figure G-2 Cost Estimates for Sewer Flushing and In-line Storage Systems

Annual operation and maintenance (O&M) costs for flushing systems can be similarly represented:

$$(O\&M)_F = \$550\ F \qquad (5)$$

These costs can be expressed in terms of the fraction of the 2,666 pipe components flushed in the 2,753 sewered acres:

$$C_F\ (\$/\text{acre}) = 6500\ X_F^{0.875} \qquad (6)$$

and

$$(O\&M)_F = 533\ X_F \qquad (7)$$

If the flushing systems are designed and operated for in-line wet weather storage, as well as dry weather flushing, the respective costs become:

$$C_{F/S}\ (\$/\text{acre}) = 7200\ X_F^{0.875} \qquad (8)$$

and

$$(O\&M)_F = 584\ X_F \qquad (9)$$

The estimates of available in-line storage capacity can be represented:

$$V_{F/S} = 0.045\ F^{0.523} \qquad (10)$$

or

$$V_{F/S} = X_F^{0.523} \qquad (11)$$

where

$V_{F/S}$ = in-line storage capacity (thousand gallons/acre).

Equation (11) can also be written:

$$S_{F/S} = 0.037\ X_F^{\ 0.523}. \qquad (12)$$

where

$S_{F/S}$ = in-line storage, inches

APPENDIX H
LAND APPLICATION SYSTEMS

APPENDIX H

LAND APPLICATION SYSTEMS

H.1 Introduction

This Appendix is intended to provide a brief state-of-the-art review of land application systems, generally, to describe an example of a specific land application project design, and to serve as a tool for the evaluation of potential land application systems in the Boston area. The present interest in land application of sewage in the United States has originated from a realization of potential benefits — water pollution control, conservation through recycling, and increased food production through agriculture. That soils can renovate or purify wastewater has long been generally known. The degree of renovation, however, has only recently been quantified and, for this reason, land application of human wastes is viewed by some as a recent development. In this regard, the design and construction of a 42 mgd land application facility at Muskegon, Michigan, represents the first large-scale United States endeavor in which agricultural recycling of wastewater nutrients is deliberately employed to achieve both a high level of agricultural productivity and a high degree of wastewater renovation.

Other benefits of land application of treated sewage, such as preservation of open spaces and maintenance of a balance between urban and agricultural land use, can be viewed as additional attributes. At present, however, revenues from agricultural production and wastewater renovation capabilities are the most practical benefits. As discussed in detail below, not all forms of land application are nutrient recycling schemes. The overland flow approach, for example, recycles only about one-third of the nitrogen in the wastewater to the terrestrial ecosystem; the remainder is returned to the atmosphere as nitrogen gas. The nitrogen gas must be biologically or chemically fixed before it is again available for plant growth.

H.2 Land Application Alternatives

Land application or treatment are terms used to describe the process of applying domestic and industrial wastewaters to soils to renovate water, recycle nutrients or dispose of waste products. Depending on the purpose, wastewaters can be applied to land for any one or a combination of the above reasons.

Land application approaches fall into three categories: irrigation, infiltration-percolation and overland flow (Figure H-1). A detailed description of these approaches can be found in the review by Pond and Crites (1975).

Irrigation

Irrigation is employed to provide both water and nutrients, such as nitrogen and phosphorus, contained in wastewater, for growing plants. Crops such as vegetables, cereals and grasses are commonly used to recycle such nutrients. The renovated water is not usually collected. Water loss occurs as a result of evapotranspiration and plant uptake, as well as by percolation to ground water. Spray irrigation is used more often than either flood or ridge-and-furrow irrigation in the eastern United States. Soil types particularly well suited to irrigation include sandy loam and silty loam soils. These soils generally are not limited by their water uptake capacity, but rather by the plants' capacity to remove nutrients from the wastewater. The nutrient found in the effluent of secondary wastewater treatment plants which requires the most careful consideration is nitrogen; its removal is ascribed mainly to crop uptake. Both the concentration of nitrogen in the wastewater and the quantity of nitrogen taken up by the crop greatly influence land area requirements. Crop uptake of nitrogen ranges between 100 and 500 lb-N/acre-year depending on the crop employed. For example, corn (silage) can remove about 160 lb-N/acre-year,* with an additional

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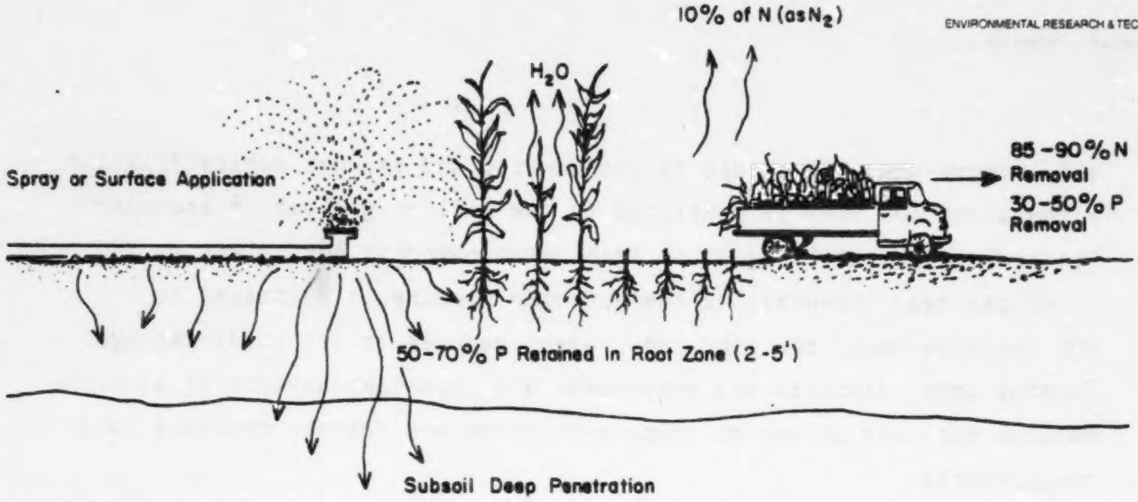
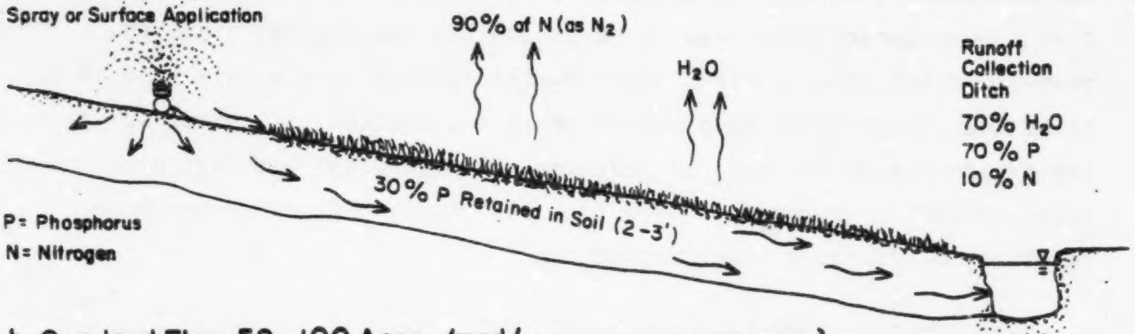
*Sopper (1974) reported in studies conducted at Penn State that Reed canary grass irrigated with treated municipal sewage effluent at two inches per week produced yields over a 6-year period which varied between 4.32 and 7.03 tons/acre-year with an average yearly nitrogen (N) removal of 340 lb/acre. In 1970, 408 lb-N and 56 lb of phosphorus (P) were removed by the Reed canary grass. This can be contrasted with removal by a row crop such as corn. For example, when corn silage was irrigated at the same rate during the same year, only 160 lb of N and 43 lb of P were removed.

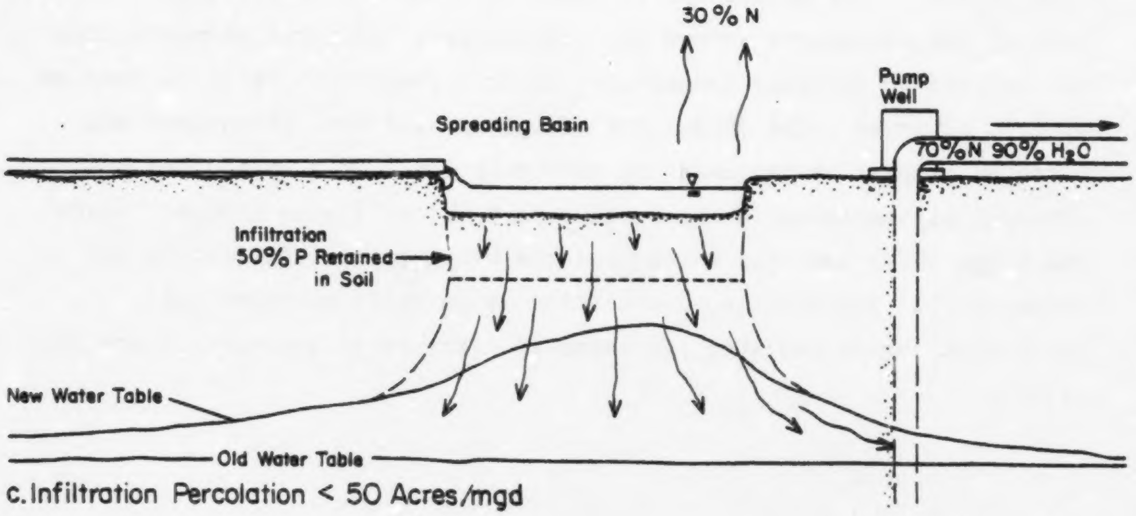
Nutrient uptake by forest systems has also been studied at Penn State. Forest systems were found to be less efficient than crop systems in removing nutrients. Hardwood forests were found to remove only 84 lb of N and 8 lb-P/acre-year when irrigated with two inches per week of effluent in 1970.


10% of N (as N_2)
H_2O
Spray or Surface Application
85 - 90% N Removal
30 - 50% P Removal
50-70% P Retained In Root Zone (2 - 5')
Subsoil Deep Penetration

a. Irrigation - 150 - 500 Acres/mgd


Spray or Surface Application
90% of N (as N_2)
H_2O
Runoff Collection Ditch
70% H_2O
70% P
10% N
30% P Retained in Soil (2 - 3')
P = Phosphorus
N = Nitrogen

b. Overland Flow 50 - 100 Acres/mgd (NON HARVESTING SITUATION)


30% N
Pump Well
Spreading Basin
70% N 90% H_2O
Infiltration
50% P Retained in Soil
New Water Table
Old Water Table

c. Infiltration Percolation < 50 Acres/mgd

Figure H-1 Comparison of Land Application Alternatives

100 lb/acre-year being lost to groundwater and through denitrification. Since about 200 lb-N is contained in one million gallons of secondary treated sewage (at 25 mg-N/l), this requirement is equivalent to 280 acres per mgd. However, if the nitrogen loading is increased to 400 lbs/acre-year, the land requirement reduces to 190 acres per mgd. Careful crop selection and management are important aspects of assuring maximum nutrient uptake by cropping systems and thereby reducing land requirements.

Spray irrigation of forested and crop land has been studied extensively at Penn State University since 1964. This pilot-scale facility has evaluated a variety of cropping systems for their renovation capabilities. Reed canary grass was found to provide the highest nitrogen removal of any crop studied. Groundwater nitrate levels were also found to be the lowest under Reed canary grass cultivation. A larger spray irrigation system (42 mgd) in Muskegon, Michigan, is just beginning its third season of operation. This facility occupies 10,000 acres and maintains 6,000 acres under irrigation.

Infiltration-Percolation

The disposal of wastewater by infiltration-percolation is accomplished on sand or sandy loam soils. Application rates are measured in feet per week as opposed to 1 to 4 inches per week used in the irrigation method. This method can be used for treatment or disposal. Since most of the wastewater enters the groundwater, infiltration-percolation can be used to recharge groundwater after a prescribed level of renovation is achieved. The renovation efficiency for both phosphorus and nitrogen removal is variable and generally low. This method has been successfully employed in the southwestern United States (Bouwer, Lance and Riggs 1974) and also throughout the New England area (Cribes and Pound 1977). Infiltration-percolation is possible wherever soil conditions permit and when increases in nitrates in groundwater are not critical.

Overland Flow

Perhaps the least exploited of the land disposal techniques is overland flow. Overland flow results when wastewater is discharged onto sloping land containing soils with low permeability. The sheet-like flow obtained on carefully graded land results in a high degree of nitrogen and BOD removal with a large proportion of the wastewater being collected as runoff. Nitrogen removal results primarily from microbial action rather than by plant uptake. The most extensive use of this technique in the United States has been for treatment of cannery wastes (Carlson, Hunt and Delaney 1974).

Soils suited for overland flow are low-permeable clay and clay loam soils. An additional requirement is that the land have a mild slope of 2% to 6% in order to avoid stagnation and puddling. A grass crop is planted primarily to prevent erosion and, to a much lesser extent, for nutrient removal. The passage of wastewater through the grass-soil environment results in mechanical filtering of suspended solids and a biodegradation of organic matter on the aerobic soil surface. Below 1 to 2 cm, the soil layers are predominantly anaerobic, creating soil conditions favorable for denitrification. Removal efficiencies of 90% have been achieved for suspended solids and BOD in Australia (Seabrook 1975) and the United States for overland flow of municipal wastes. These removals have been achieved at loading rates of 1,300 lbs-N/acre-year (Carlson, Hunt and Delaney 1974). This rate is equivalent to a land requirement of about 50 acres/mgd as opposed to 150 to 500 acres/mgd for irrigation. While the effluent from overland flow treatment is relatively low in nitrogen, its phosphorus content is high and as such cannot be discharged directly to most receiving waters. Overland flow can be used in conjunction with infiltration-percolation or spray irrigation, thus matching the highly efficient nitrogen removal of one process with the highly efficient phosphorus removal of another.

H.3 Wastewater Characteristics

Before wastewater is applied to land, it is pretreated, though not to the extent usually considered to be conventional secondary treatment. Pretreatment typically involves screening, followed by a series of aerated ponds and a series of non-aerated settling ponds. The pretreated wastewater may then be stored and sometimes disinfected prior to irrigation. The composition of the resulting pretreated wastewater, particularly its nitrogen concentration, serves as a major design criterion and, as a result, influences both the land area requirement and the selection of the land application approach.

H.4 Selection Criteria

The criteria considered in selecting a land treatment site include population densities, conveyance land values, length of boundaries, road intersections, existing parcel sizes and soil types. Of the factors listed above, it is generally desirable that the first four are minimal, while large parcel sizes would facilitate acquisition. Soil types will strongly influence general process selections. Climatic factors place definite limitations on the design and operation of land treatment systems. In the northeast, land treatment by spray irrigation cannot be a year-round operation. Because nutrient uptake by plants can occur only during the growing season, which is six to eight months out of the year in eastern Massachusetts, storage of wastewater must be provided for the periods during which application is not feasible.

H.5 Example Description of a Land Application System (Irrigation)

The design of a land application system consists of three components: wastewater conveyance, pre-treatment and land application. The conveyance system transmits the raw sewage to the pre-treatment facility. Initially the flows are screened and grit is removed. The sewage is then aerated in surface aerating lagoons for seven days. Storage is provided following this treatment, with a maximum capacity of approximately 175 days. This storage facility serves three purposes. As well as providing storage for the nonoperating period and contingencies, the storage ponds also serve as sludge setting lagoons. The long detention period eliminates the necessity for disinfection by chlorination prior to irrigation.

Following pre-treatment and storage, wastewater is transmitted to the irrigation sites through the main distribution pumping station. Distribution pipes discharge to irrigation laterals, which feed the center pivot irrigating machines. The renovated waters percolate through the soil column either to the groundwater table or into drains under the sites. These underdrains provide the means for selective distribution of renovated water for groundwater replenishment or to surface waters for flow augmentation. Figure H-2 shows schematically the general layout and process flow of a land treatment irrigation facility.

Effluent Quality

One of the primary purposes of applying wastewater to land is to renovate or purify water, others being groundwater recharge and agricultural irrigation. Although the degree of renovation is approach-specific for certain parameters, renovation efficiencies for suspended solids and 5-day biochemical oxygen demand (BOD_5) are routinely 99% for all three land application approaches. Similar removal efficiencies are expected for heavy metals, phosphorus and viruses when spray irrigation is employed. Nitrogen removal efficiency is expected to be approximately 90% for the spray irrigation process. Drainage water quality data from the Muskegon Land Application Facility during its first summer of operation is shown in Table H-1.

Irrigable Land Requirements

A hydraulic loading rate of 3.3 inches per week is used throughout the operating period of the year. If an average 7-month operating period is assumed, the irrigable land requirement will be 144 acres per mgd.

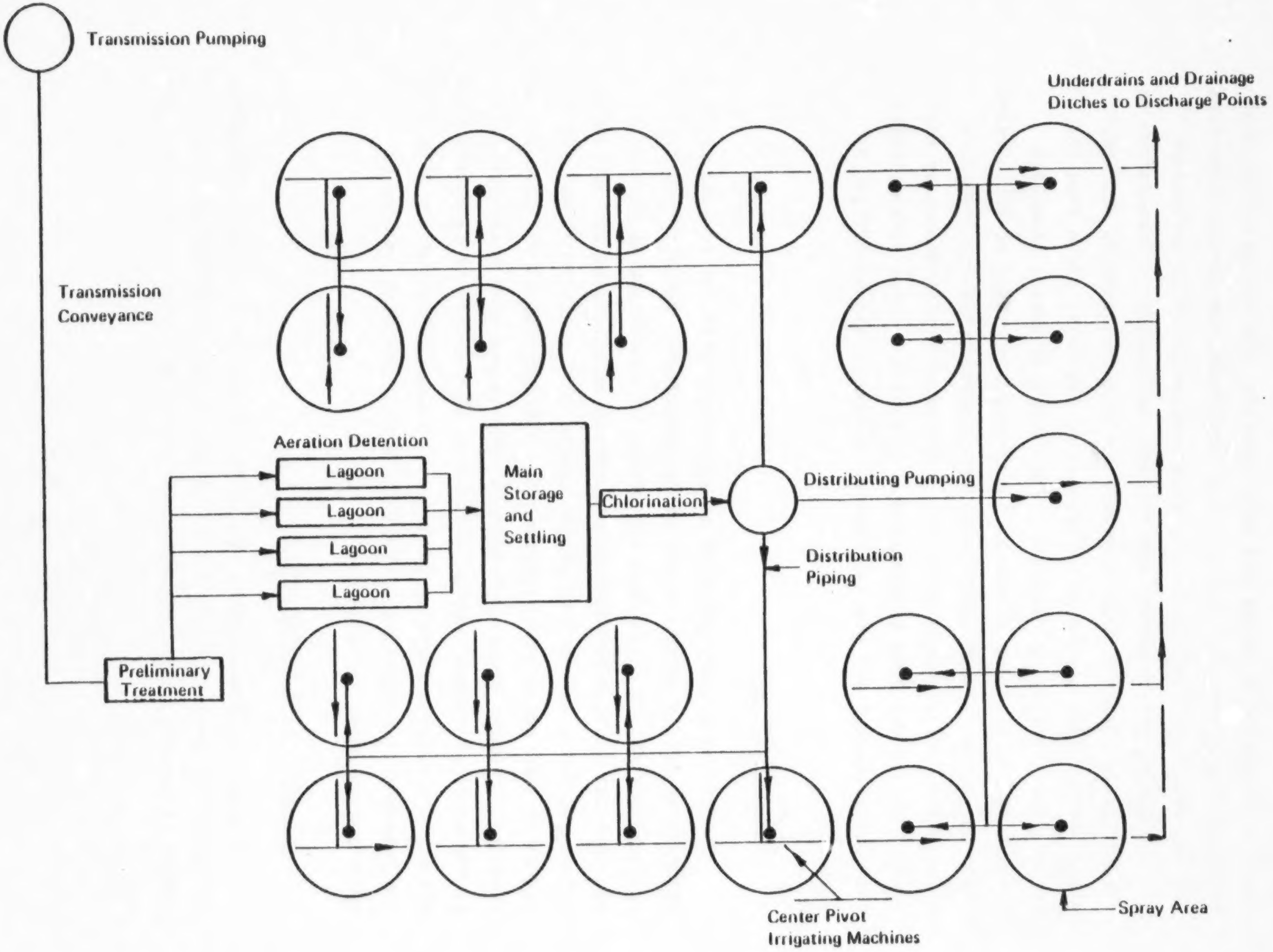

Transmission Pumping
Transmission Conveyance
Preliminary Treatment
Aeration Detention
Lagoon
Lagoon
Lagoon
Lagoon
Main Storage and Settling
Chlorination
Distributing Pumping
Distribution Piping
Underdrains and Drainage Ditches to Discharge Points
Center Pivot Irrigating Machines
Spray Area

Figure II-2 Schematic Representation of Land Treatment Facility and Process Flow

TABLE H-1

DRAINAGE WATER QUALITY REPORTED AT MUSKEGON, MICHIGAN*

Constituent	Concentration
BOD_5	3 mg/l
Suspended Solids	7 mg/l
Ammonia Nitrogen as N	0.6 mg/l
Nitrate Nitrogen as N	1.9 mg/l
Total Phosphorus	0.05 mg/l
Zinc	0.07 mg/l
Fecal Coliform	< 100/100 ml

*Walker, John, M., September 1976. Wastewater: Is Muskegon County's Solution your Solution?, U.S. Environmental Protection Agency, Region V

TABLE H-2

LAND TREATMENT SITES IN PRINCE GEORGE'S COUNTY, MARYLAND
ACRES OF BUFFER (PERCENT OF TOTAL)

Buffer Width	Site A	Site B	Site C	Site D
200 ft	1,360 (11%)	1,550 (14%)	1,340 (7%)	1,400 (6%)
300 ft	2,030 (17%)	2,320 (20.8%)	2,011 (10.5%)	2,100 (9%)
400 ft	2,710 (22.5%)	3,100 (27.8%)	2,681 (14%)	2,800 (12%)

Nonirrigable Land Requirements

The net irrigable field area includes only part of the total land requirement for a land treatment facility. Additional land is needed for buffer zones, storage areas and contingency areas. In addition, some portions of any site may be considered nonusable for irrigation due to steep slopes or wetlands, although they may be useful for buffer areas if located appropriately.

Buffer zones can vary in width from 200 to 500 feet or more, depending on the adjacent land use. The percentage of the total site area needed for buffer zones is calculated by measuring road lengths, housing development perimeters and site boundaries. Table H-2 lists data from a number of land treatment sites analyzed in Prince George's County, Maryland, using three different buffer zone widths (Process Research, Inc., 1975).

Assuming an operating period of 7 months per year and a 7-day pretreatment period, the total area required for storage and pretreatment amounts to about 45 acres per mgd treatment capacity. These requirements are summarized in Table H-3.

Total Land Requirements

Total land requirements are the sum of irrigated land, storage and pretreatment areas, buffer zones and other nonusable areas. With 20% assumed for the buffer and other nonusable areas, the total land requirement breakdown is as shown in Table H-4.

Irrigation Systems

Three sprinkler systems may be considered for applying wastewater. The following discussion briefly indicates the relative advantages and disadvantages of each in terms of capital costs, maintenance costs and equipment performance.

TABLE H-3

STORAGE AND PRETREATMENT AREA REQUIREMENTS FOR LAND TREATMENT SYSTEMS

Component	Acres/mgd
Nonoperating period, 150 days	37.5
Downtime during rainfall events, 15 days	3.7
Direct rainfall on ponds (less evaporation)	2.5
Pretreatment, 7 days	1.8
Total	45.5

TABLE H-4

TOTAL LAND REQUIREMENTS

Land Use	Acres/mgd
Irrigation	144
Storage/Pretreatment	45
Buffer and other (20%)	38
Total	227

a) Solid-Set Sprinklers

A solid-set sprinkler system is entirely buried, except for the actual spray head and riser. This system layout could be both an advantage, because the pipelines are out of the way, and a disadvantage in terms of maintenance. Because each sprinkler covers a relatively small area, the capital costs can become excessive. Also, the height of the cover crop can have a limiting effect on the utility of these units. A tall cover crop such as corn would require oversized risers and, thus, increased capital and maintenance costs.

b) Travelling Sprayers

The unit cost per acre is considerably lower for this system than for the solid-set system, because of the larger area covered by each unit. Operation and maintenance costs could be higher, because of the more sophisticated equipment involved. These units are excellent for irregular terrain and are not affected by crop height. They do require an open path for movement but this loss of irrigable land is recovered by the large field area covered by each unit.

c) Center Pivot Irrigating Machines

Center pivot irrigators are used extensively throughout the United States for standard irrigating purposes. At Muskegon County, Michigan, center pivot irrigators with low-pressure downspray nozzles were used for land application of wastewater by spray irrigation. The field area covered is variable and can be as large as 140 acres. Unit costs for these machines are approximately equal to those for the travelling sprayers. They do require a fairly uniform topography for low maintenance operation, but can function efficiently on slopes up to 10%. Center pivot machines were used as a basis for costing land treatment facilities in the Boston area.

H.6 Technological Advances

Applying treated sewage effluents to land may take on somewhat different emphasis in the future. A number of recent studies* have shown that the passage of sewage through artifical marshes planted with bulrushes and reeds resulted in wastewater renovation superior to that resulting from conventional secondary treatment, in terms of both nutrient removal and BOD reduction. Since on an annual basis marsh ecosystems are more productive than terrestrial (agricultural) ecosystems, mechanical harvesting with subsequent composting of crops can be expected to result in a higher degree of nutrient removal. The release of oxygen through the root systems of bulrushes contributes directly to oxygenation of the wastewater. In addition, the microflora associated with the marsh ecosystem is reported to be highly efficient in causing die-off of coliforms, thereby eliminating the need for chlorination. The wastes generated by between 200 and 2,000 people per day can be treated on one acre of marsh. This is approximately 2- to 20-fold more efficient than the conventional land treatment presently being considered and would result in proportionally smaller land requirements. This approach has been suggested for further examination in the DWPC Charles River Water Quality Management Plan (DWPC 1976a.).

H.7 Land Treatment Costs

Cost estimates for land treatment systems were developed directly from: Costs of Wastewater Treatment by Land Application, EPA-430/9-75-003 (June 1975), by Metcalf and Eddy, Inc. Design assumptions for the land treatment system components were those from this publication.

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*These studies were presented at the International Conference on Biological Water Quality Improvement Alternatives, Center for Ecological Research in Planning and Design, University of Pennsylvania, March 3, 4 and 5, 1975.

The base date for the original Metcalf and Eddy cost estimates was February 1973 (ENR Construction Cost Index 2000). These original cost estimates were increased by ten percent to ENR 2200. The amortized annual capital costs were originally computed by Metcalf and Eddy using a capital recovery factor (CRF) of 0.0845. They were adjusted in this analysis to CRF 0.0858 and ENR 2200 by multiplying by the factor 1.1169.

APPENDIX I

WATER USE (BENEFIT) POTENTIALS

APPENDIX I

WATER USE (BENEFIT) POTENTIALS

The basic measure of relative value, or water use potential, has been a mathematical supply-demand interaction model (Battelle 1975). The potential interaction has been modeled to vary with the product of supply and demand and inversely with the square of the distance between the supply and the demand. Models with these premises, also referred to as gravity-models, are typically used in transportation planning, recreational site locating and distribution point siting. For measuring recreational water use potential, supply has been assumed proportional to the length of a river or coastal water segment and demand from any location has been assumed proportional to that location's population. For a given segment length, then, the model would project a higher use potential the nearer that water segment is to its potential users. While this model is intended primarily as a measure of the relative benefits of providing clean (swimmable-fishable) waters at different locations, conversely it might also be regarded as a measure of the relative costs of lost opportunities associated with not cleaning up the waters.

The two versions of the use potential model which have been used are

$$I_j = S_j \sum_i \frac{D_i}{R_{ij}^2} \qquad (1)$$

and

$$\overline{I}_j = S_j \sum_i \frac{\dfrac{D_i}{R_{ij}^2}}{\sum\limits_K \dfrac{S_j}{R_{iK}^2}} \qquad (2)$$

where

I_j = "unlimited" use potential for water segment j, (1,000's population/mile);

$\overline{I}_j$ = "constrained" use potential for water segment j, (1,000's population);

S_j = length of water segment j, (miles);

D_i = population at location i, (1,000's); and

R_{ij} = distance between population location i and water segment j, (miles).

Equation (1) allows a limitless demand for clean water that, for any single water segment location, results in a use potential dependent only upon the length of the segment and the population distribution around that segment. With Equation (1), the use potential for any water segment is independent of the presence of other supplies: for example, clean water in other nearby segments. Equation (2) considers fixed demands for clean water that are proportional to populations, and distributes the interactions of those demands among all possible clean water locations. Equation (2), then, is a measure of the relative value of clean water in one location if clean water existed everywhere.

For this application, the models were employed as follows.

- x-y coordinate grids were overlaid on metropolitan Boston-area census tract maps and centroid coordinates and populations of each census tract were recorded;
- each of the metropolitan area rivers and the Boston Harbor shoreline were divided into 4- or 5-mile segments and the lengths and mid-point coordinates of each segment were recorded;
- this data base was then input to a computer programmed to calculate and tabulate water use potentials for each of 69 segments by Equations (1) and (2); and
- for each water segment, the two use-potential measures were divided by the segment length and these length-normalized use potentials were tabulated.

Mid-point locations for the 69 water use potential segments are shown on Figure I-1. Computed values for I_j, $\overline{I}_j$, I_j/S_j and $\overline{I}_j/S_j$ are tabulated in Table I-1.

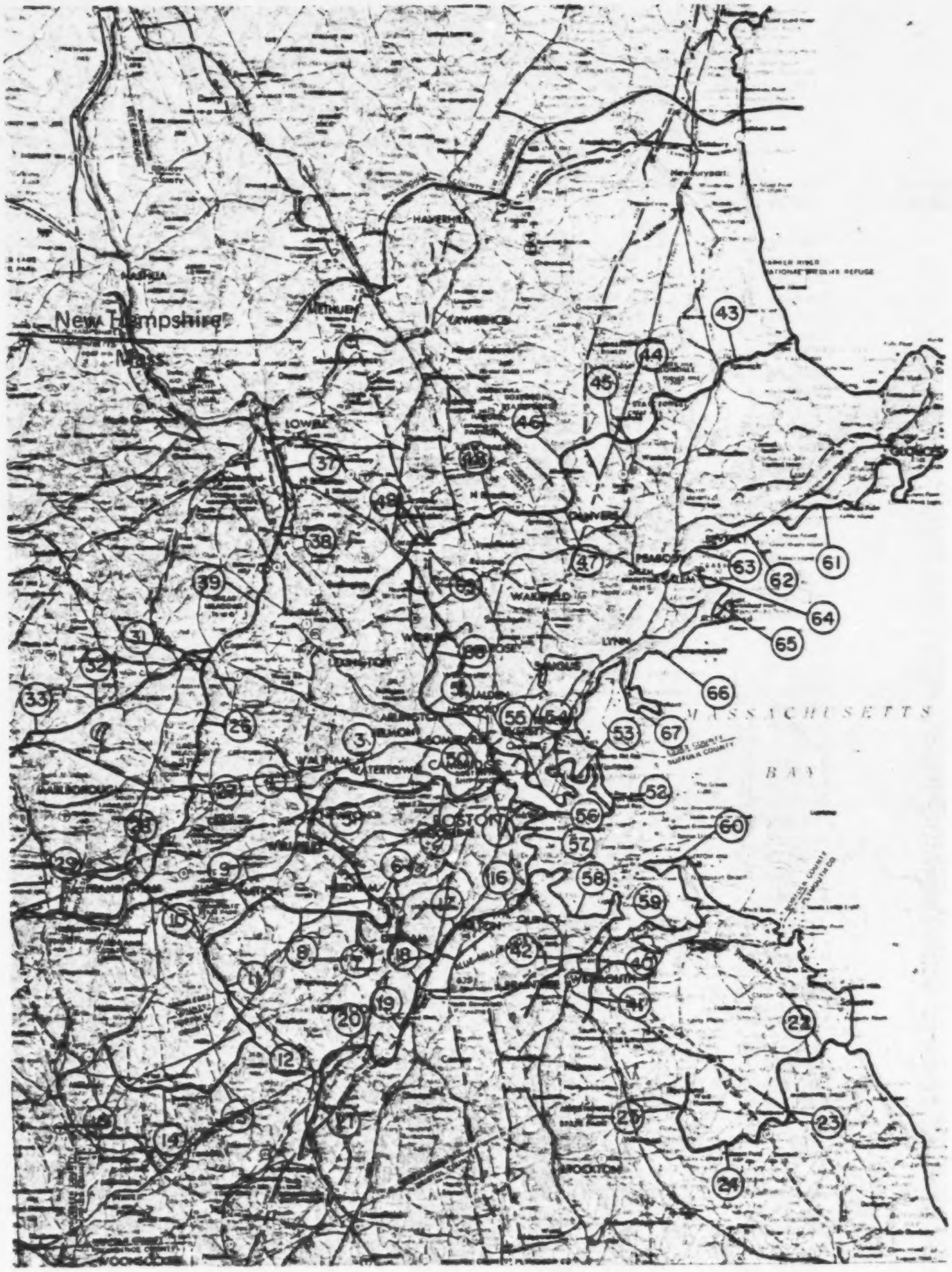
New Hampshire
Mass.
HAVERHILL
LAWRENCE
LOWELL
DANVERS
WAKEFIELD
LEXINGTON
WALTHAM
WATERTOWN
CAMBRIDGE
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Figure I-1 Midpoint Locations for Water Use Potential Segments

TABLE I-1

COMPUTED VALUES FOR WATER USE POTENTIALS

			Water Use Potentials		Normalized Potentials	
Segment Number	Body of Water	Segment Miles	Unlimited Demand Eq(1),I_j	Fixed Demand Eq(2),$\overline{I}_j$	I_j/S_j	$\overline{I}_j/S_j$
1	Charles R.	0 - 5.3	2,028	193	383	36
2	Charles R.	5.3 - 10.6	1,231	142	232	27
3	Charles R.	10.6 - 15.9	707	96	133	18
4	Charles R.	15.9 - 21.2	405	60	76	11
5	Charles R.	21.2 - 26.5	514	66	97	13
6	Charles R.	26.5 - 31.8	790	80	149	15
7	Charles R.	31.8 - 37.1	378	55	71	10
8	Charles R.	37.1 - 42.4	186	37	35	7
9	Charles R.	42.4 - 47.7	130	30	25	6
10	Charles R.	47.7 - 53.0	106	25	20	5
11	Charles R.	53.0 - 58.3	91	24	17	4
12	Charles R.	58.3 - 63.6	86	24	16	5
13	Charles R.	63.6 - 68.9	60	19	11	4
14	Charles R.	68.9 - 74.2	93	21	17	4
15	Charles R.	74.2 - 79.5	70	18	13	3
16	Neponset R.	0 - 5.0	838	109	168	22
17	Neponset R.	5.0 - 10.0	775	105	155	21
18	Neponset R.	10.0 - 15.0	256	51	51	10
19	Neponset R.	15.0 - 20.0	200	43	40	9
20	Neponset R.	20.0 - 25.0	134	32	27	6
21	Neponset R.	25.0 - 30.0	118	26	24	5
22	North R.	0 - 5.0	60	22	12	4
23	North R.	5.0 - 10.0	54	20	11	4
24	North R.	10.0 - 15.0	75	24	15	5
25	North R.	15.0 - 20.0	128	29	26	6
26	Sudbury R.	0 - 4.0	103	23	26	6
27	Sudbury R.	4.0 - 8.0	98	23	25	6
28	Sudbury R.	8.0 - 12.0	200	36	50	9
29	Sudbury R.	12.0 - 16.0	138	34	35	8
30	Sudbury R.	16.0 - 20.0	73	20	18	5
31	Assabet R.	0 - 5.0	110	28	22	6
32	Assabet R.	5.0 - 10.0	189	29	33	6
33	Assabet R.	10.0 - 15.0	141	29	28	6
34	Assabet R.	15.0 - 20.0	41	14	8	3
35	Assabet R.	20.0 - 25.0	61	18	12	4
36	Assabet R.	25.0 - 30.0	50	15	10	3
37	Concord R.	0 - 5.0	116	38	23	8
38	Concord R.	5.0 - 10.0	115	34	23	7
39	Concord R.	10.0 - 15.0	142	35	28	7
40	Weymouth B.	0 - 4.0	126	27	31	7
41	Weymouth B.	4.0 - 8.0	173	36	43	9
42	Weymouth F.	0 - 2.0	155	35	78	17
43	Ipwich R.	0 - 4.0	39	13	10	3
44	Ipswich R.	4.0 - 8.0	58	19	14	5
45	Ipswich R.	8.0 - 12.0	78	21	20	5
46	Ipswich R.	12.0 - 16.0	108	27	27	7
47	Ipswich R.	16.0 - 20.0	436	35	109	9
48	Ipswich R.	20.0 - 24.0	158	33	39	8
49	Ipswich R.	24.0 - 28.0	154	35	39	9
50	Mystic R.	0 - 5.5	1,198	151	218	28
51	Mystic R.	5.5 - 11.0	1,384	135	252	25
52	Boston Har.	0 - 4.0	188	31	47	8
53	Boston Har,	4.0 - 8.0	522	65	130	16
54	Boston Har.	8.0 - 12.0	409	52	102	13
55	Boston Har.	12.0 - 16.0	546	71	136	18
56	Boston Har.	16.0 - 20.0	332	50	83	12
57	Boston Har.	20.0 - 24.0	649	85	162	21
58	Boston Har.	24.0 - 28.0	115	23	29	6
59	Boston Har.	28.0 - 32.0	156	26	39	6
60	Boston Har.	32.0 - 36.0	78	18	20	4
61	N. Coastal	0 - 4.0	59	20	15	5
62	N. Coastal	4.0 - 8.0	101	24	25	6
63	N. Coastal	8.0 - 12.0	300	57	75	14
64	N. Coastal	12.0 - 16.0	450	52	113	13
65	N. Coastal	16.0 - 20.0	180	28	45	7
66	N. Coastal	20.0 - 24.0	254	39	64	10
67	N. Coastal	24.0 - 28.0	219	50	55	13
68	Mystic R.	11.0 - 16.5	577	88	105	16
69	Mystic R.	16.5 - 22.0	439	63	80	11

The length-normalized versions of Equations (1) and (2) were intended to eliminate influences of the slightly different segment lengths in the various basins. Results from these versions allow comparisons of use potentials per constant unit length among all segments. While the normalized Equation (2) dampens some of the fluctuations resulting from the normalized Equation (1), there are no predominant differences between use potentials calculated by the two versions of the model. All water segments are ranked in Table I-2 in order of the two normalized use potential measures: I_j/S_j and $\bar{I}_j/S_j$. There is some minor positional shifting of segment rankings between the two measures, but no major differences are apparent.

The results from Equation (2) are perhaps more interesting, since some immediate physical significance can be attributed to them. Water use potentials computed by this equation can be interpreted loosely as the metropolitan Boston area population most likely to benefit by acceptable water quality at a given location, assuming equivalent water quality and other amenities to exist simultaneously at all other locations in the metropolitan area. Likewise, the length-normalized version of Equation (2) can be interpreted for each segment as the population per mile of segment likely to benefit from acceptable water quality. Results from Equation (2) are displayed in Figures I-2 through I-5 for all major water segments in the metropolitan Boston area. The significant increase in projected relative water quality values with proximity to potential user populations is clear from these figures. Total use potentials for individual river and coastal basins are listed in Table I-3, as computed by both equations.

TABLE I-2

WATER USE POTENTIAL RANKING

	Normalized Equation (1)			Normalized Equation (2)		
Ranking	Water	Segment	I_j/S_j	Water	Segment	T_j/S_j
1.	Charles	1	383	Charles	1	36
2.	Mystic	51	252	Mystic	50	28
3.	Charles	2	232	Charles	2	27
4.	Mystic	50	218	Mystic	51	25
5.	Neponset	16	168	Neponset	16	22
6.	Harbor	57	162	Harbor	57	21
7.	Neponset	17	155	Neponset	17	21
8.	Charles	6	149	Charles	3	18
9.	Harbor	55	136	Harbor	55	18
10.	Charles	3	133	Weymouth F.	42	17
11.	Harbor	53	130	Harbor	53	16
12.	N. Coastal	64	113	Mystic	68	16
13.	Ipswich	47	109	Charles	6	15
14.	Mystic	68	105	N. Coastal	63	14
15.	Harbor	54	102	Harbor	54	13
16.	Charles	5	97	N. Coastal	64	13
17.	Harbor	56	83	N. Coastal	67	13
18.	Mystic	69	80	Charles	5	13
19.	Weymouth F.	42	78	Harbor	56	12
20.	Charles	4	76	Mystic	69	11
21.	N. Coastal	63	75	Charles	4	11
22.	Charles	7	71	Charles	7	10
23.	N. Coastal	66	64	Neponset	18	10
24.	N. Coastal	67	55	N. Coastal	66	10
25.	Neponset	18	51	Sudbury	28	9
26.	Sudbury	28	50	Weymouth B.	41	9
27.	Harbor	52	47	Ipswich	49	9
28.	N. Coastal	65	45	Ipswich	47	9
29.	Weymouth B.	41	43	Neponset	19	9
30.	Neponset	19	40	Sudbury	29	8
31.	Harbor	59	39	Harbor	52	8
32.	Ipswich	49	39	Concord	37	8
33.	Assabet	32	38	N. Coastal	65	7
34.	Charles	8	35	Charles	8	7
35.	Sudbury	29	35	Concord	39	7
36.	Weymouth B.	40	31	Weymouth B.	40	7
37.	Harbor	58	29	Concord	38	7
38.	Concord	39	28	Ipswich	46	7
39.	Assabet	33	28	Harbor	59	6
40.	Ipswich	46	27	Neponset	20	6
41.	Neponset	20	27	N. Coastal	62	6
42.	Sudbury	26	26	North R.	25	6
43.	North R.	25	26	Assabet	32	6
44.	N. Coastal	62	25	Assabet	33	6
45.	Charles	9	25	Sudbury	27	6
46.	Sudbury	27	25	Sudbury	26	6
47.	Neponset	21	24	Harbor	58	6
48.	Concord	37	23	Charles	9	6
49.	Concord	38	23	Assabet	31	6
50.	Assabet	31	22	Ipswich	45	5
51.	Charles	10	20	Neponset	21	5
52.	Harbor	60	20	N. Coastal	61	5
53.	Ipswich	45	20	Sudbury	30	5
54.	Sudbury	30	18	North R.	24	5
55.	Charles	14	17	Charles	10	5
56.	Charles	11	17	Ipswich	44	5
57.	Charles	12	16	Charles	12	5
58.	North R.	24	15	Charles	11	4
59.	N. Coastal	61	15	North R.	22	4
60.	Ipswich	44	14	Harbor	60	4
61.	Charles	15	13	North R.	23	4
62.	Assabet	35	12	Charles	14	4
63.	North R.	22	12	Charles	13	4
64.	Charles	13	11	Assabet	35	4
65.	North R.	23	11	Charles	15	3
66.	Assabet	36	10	Ipswich	43	3
67.	Ipswich	43	10	Assabet	36	3
68.	Assabet	34	8	Assabet	34	3

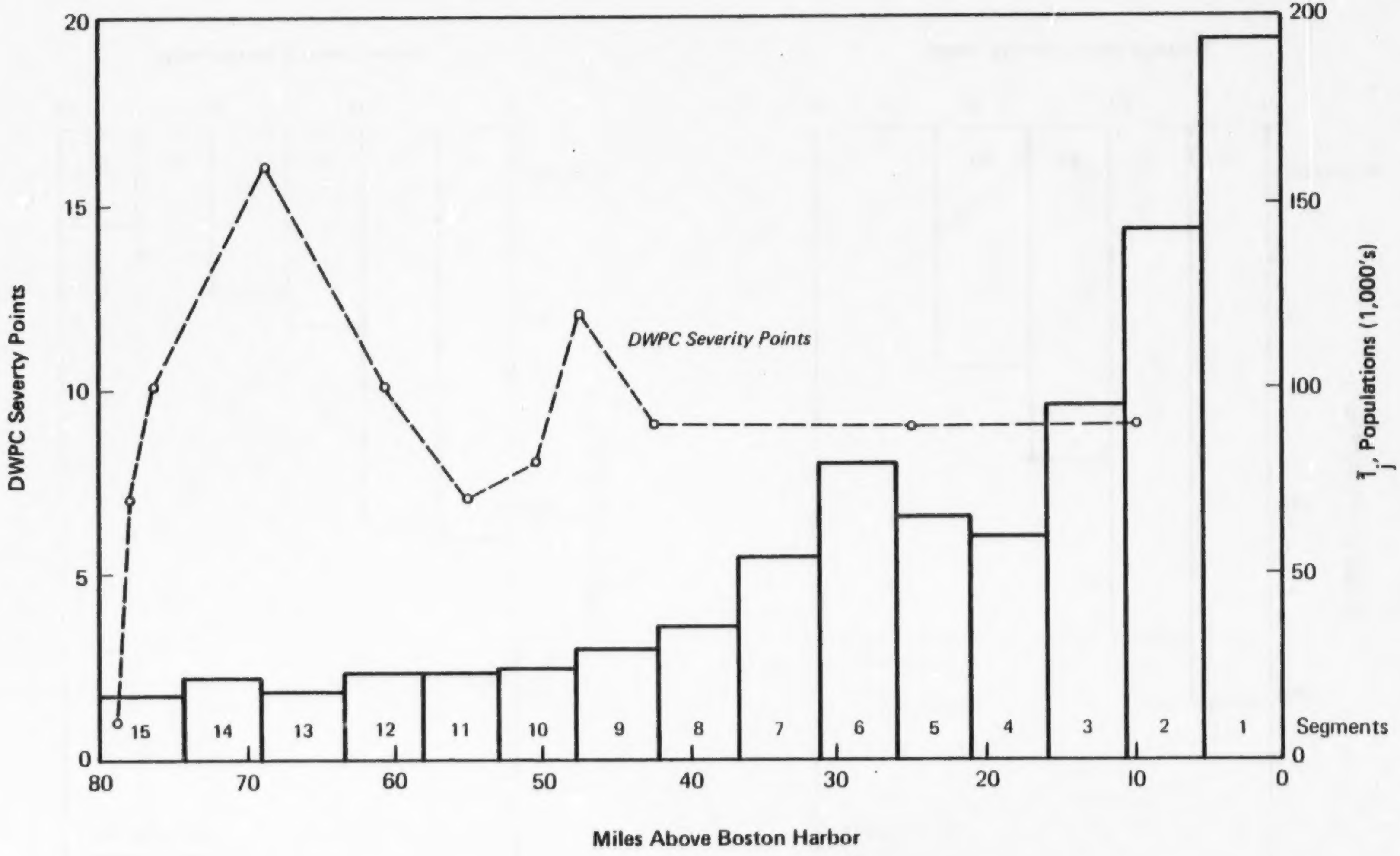

Figure I-2 Charles River Use Potentials

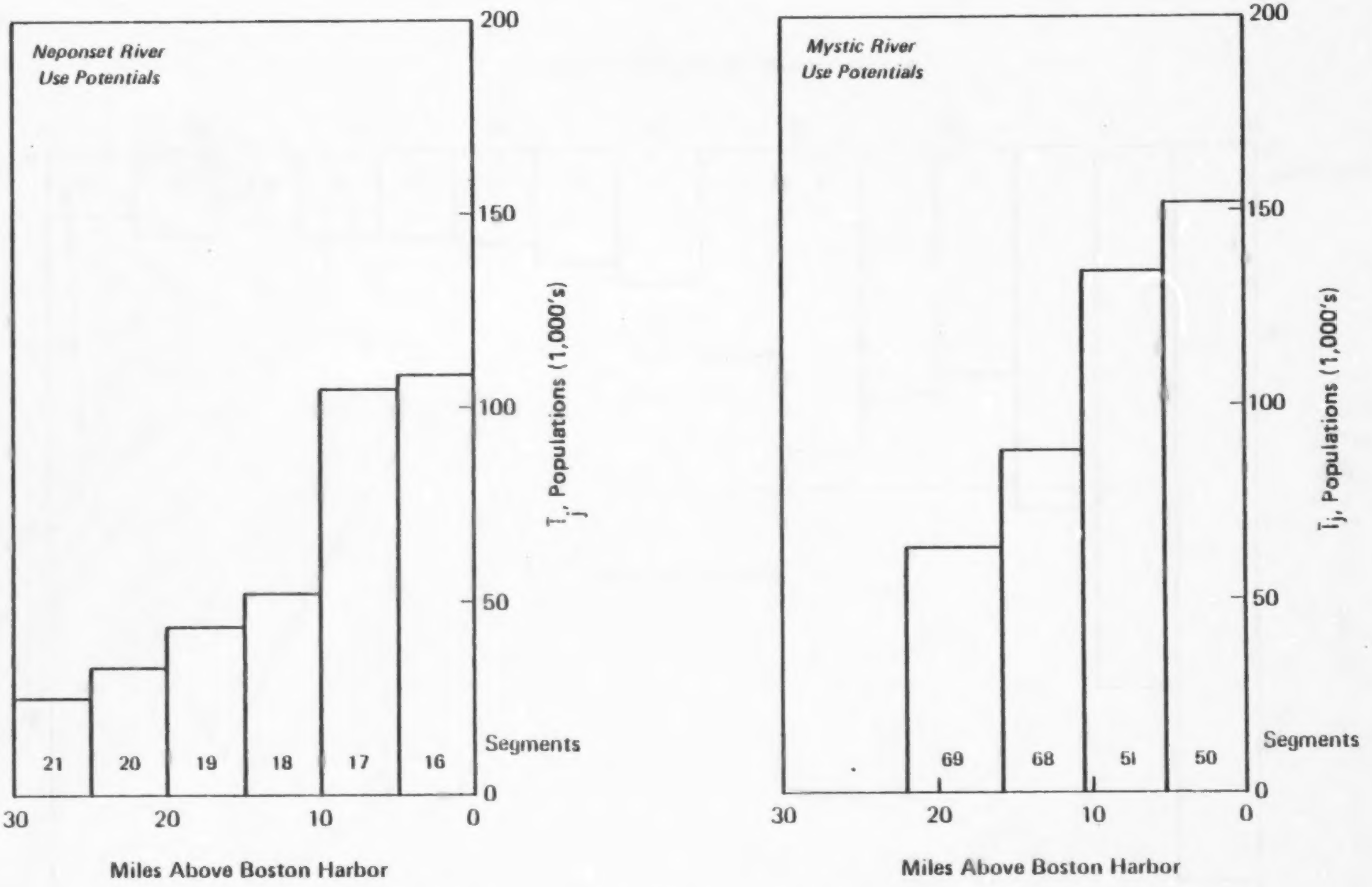

Figure I-3 Water Use Potentials

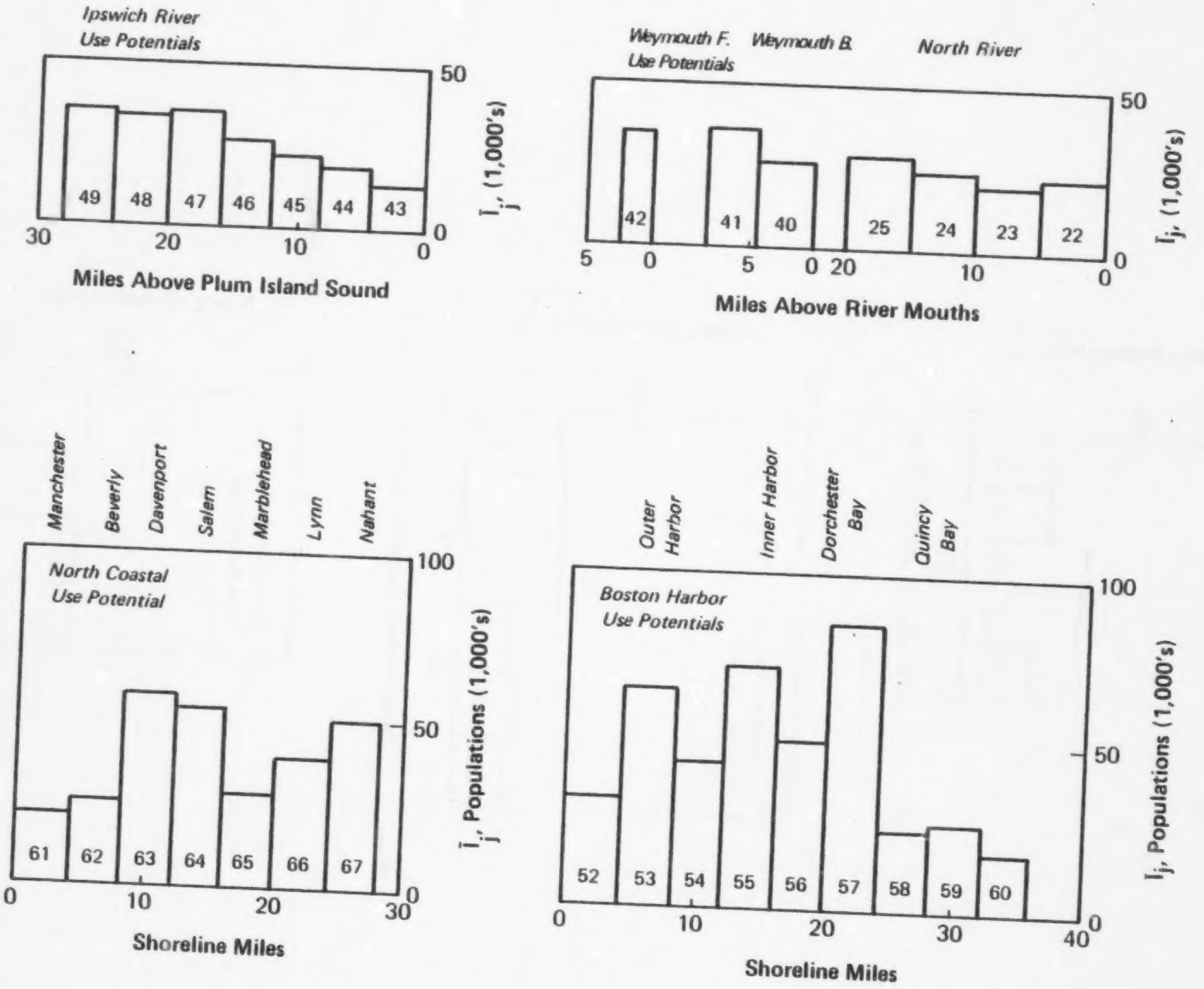

Figure I-4 Water Use Potentials

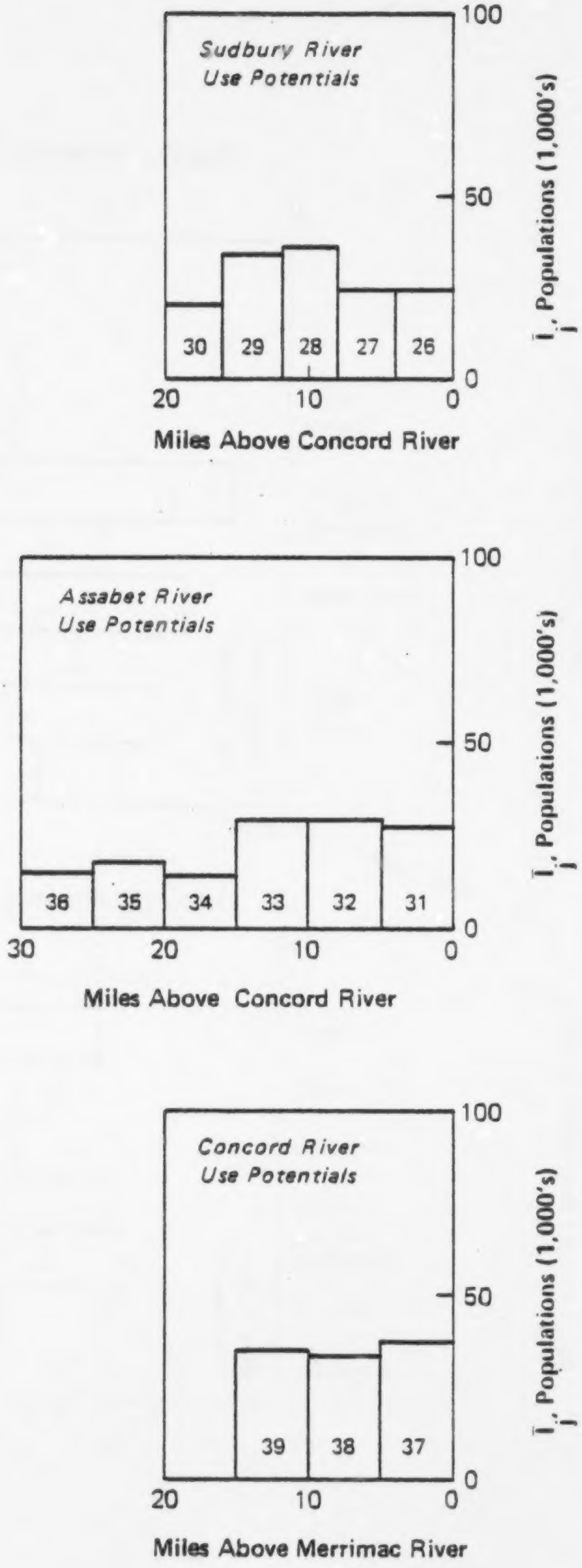

Figure I-5 Water Use Potentials

TABLE I-3

TOTAL RIVER BASIN USE POTENTIALS

	Location	Equation (1) ΣI_j	Equation (2) $\Sigma \bar{I}_j$
1.	Charles River	6,274	889
2.	Mystic River	3,598	437
3.	Boston Harbor	2,995	420
4.	Neponset River	2,320	366
5.	SUASCO Basin	1,576	376
6.	North Coastal	1,563	269
7.	Ipswich River	1,031	183
8.	North River	316	95
9.	Weymouth-Back River	299	63
10.	Weymouth-Fore River	155	34